VALIDATION OF TWO NEUROPSYCHOLOGICAL BATTERIES FOR ASSESSING FITNESS TO DRIVE IN PEOPLE WITH MULTIPLE SCLEROSIS

Thesis submitted for the degree of Doctor of Clinical Psychology

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by

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DECLARATION

This work has not been submitted for any other degree or to any other institution

STRUCTURE AND WORD COUNT

This thesis contains three sections:

Section One: Literature Review

Section Two: Research Report

Section Three: Appendices

This thesis has been prepared in accordance with the style of the *British Journal of Clinical Psychology* and the *American Psychological Association Manual* (6th ed.)

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THESIS ABSTRACT

This thesis consists of a literature review and a research project investigating fitness to drive in people with multiple sclerosis (MS). Driving ability is often affected in individuals with neurological conditions, but assessment methods for determining safety to drive are inconsistent and lack evidence-base. The literature review explored a range of factors that may be related to driving ability in individuals with MS. Studies have mostly emphasised the importance of cognitive abilities when assessing fitness to drive in this population. Findings were presented according to a comprehensive model of driving and clinical implications were summarised. Suggestions for future research in this area were formulated.

The research report presented a study examining the concurrent validity of two neuropsychological batteries that have been previously validated against an on-road test. The *MS-Driver's Screening Assessment* (MSDSA) has been specifically developed for people with MS, whereas the *Rookwood Driving Battery* (RDB) has been developed for all neurological conditions and it is widely used in clinical practice. This study also explored whether individual subtests of each battery could predict either *pass/fail* classifications or overall scores. Twenty-nine individuals with MS were recruited via their clinicians and completed both batteries. There was moderate agreement between MSDSA and RDB for *pass/fail* classifications. The MSDSA could better identify individuals who may be unsafe to drive compared to the RDB. It was established that attention, visuospatial and executive abilities are predictive of driving ability in this population. Methodological limitations were presented and a larger study was recommended to compare discrepancies between the two batteries against an on-road test.

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And to my mother for her courage and resilience….

CONTENTS

LIST OF TABLES AND FIGURES **Page**

Section One: Literature Review

Section Two: Research Report

Section One: LITERATURE REVIEW

Factors Relating to Driving Ability in Multiple Sclerosis: A Systematic Review

Abstract

Objectives. The importance of assessing fitness to drive in people with neurological conditions is recognised. This review aimed at investigating physical, cognitive, sociodemographic and driving-related factors relating to driving ability in people with multiple sclerosis.

Methods. A systematic literature search of electronic databases from their inception to year 2012 was performed. Factors related to driving performance were identified using a conceptual model of driving. Different outcome measures were included to assess driving ability. Methodological quality of studies reviewed was assessed.

Results. Fourteen studies were identified that met the eligibility criteria. The relationship between driving and various neuropsychological tests was outlined. Specific tests that assess cognitive domains of attention, information processing, visuospatial and executive skills were found to be significantly associated with a range of driving outcomes. The Stroke Driver's Screening Assessment was the most consistent cognitive predictor of on-road driving performance. There was some evidence that road sign knowledge and modifications in driving behaviours could influence driving outcomes. Additional factors relevant to driving ability, such as physical disability, sensory function and sociodemographic characteristics yielded inconsistent results.

Conclusions. A combination of cognitive tests tapping multiple cognitive domains relevant to driving ability could be used in people with MS. Methodological limitations and inconsistent findings between studies were discussed. Future better-quality research is required to determine the clinical utility of cognitive tests for assessing fitness to drive in this population.

Factors Relating to Driving Ability in Multiple Sclerosis: A Systematic Review

Driving is essential for maintaining an independent lifestyle and can impact on an individual's quality of life. It is an important activity of daily living not only for healthy adults, but also for adults with medical conditions and disabilities (Ryan et al., 2009). Most individuals who were driving prior to an acquired brain injury wish to resume driving and most of those with progressive neurological conditions wish to continue driving (Lincoln & Radford, 2012). Although the ability to drive enhances autonomy, it also poses potential risks for the individual and the public if there is evidence that driving capacity is affected (Drivers Medical Group, 2012).

Driving is a complex and diverse task that requires a range of physical, cognitive and emotional abilities. There is increasing evidence that such abilities are affected in neurological populations who may no longer be fit to drive because of acquired or progressive damage in the nervous system (McKenna, 1998). The impact of a neuropsychological condition on driving ability can be described according to the International Classification of Functioning, Disability and Health (ICF) (World Health Organisation [WHO], 2002). Based on this biopsychosocial model, driving a car can be determined by the dynamic interaction between a *health condition*, which is subdivided into functional impairments, activity limitations and participation restrictions, as well as a range of *contextual factors*, which are comprised of environmental influences and personal characteristics (Devos, 2011).

Abilities that underlie driving behaviour could be significantly impaired in individuals with multiple sclerosis as they have been shown to have a higher crash and traffic violation rate compared to healthy controls (Knecht, 1977; Lings, 2002). There is some understanding regarding driving behaviours in this condition, but recent studies have emphasised the need to investigate which disease characteristics or impairments may be associated with a decline in driving performance (Bobholz & Rao, 2003).

Multiple Sclerosis

Multiple Sclerosis (MS) is a common deteriorating neurological condition that is estimated to affect approximately 2.5 million people worldwide (WHO, 2006). It is characterized by progressive and unpredictable episodes of axonal demyelination resulting in lesions on nerve fibres in the brain, brain stem and spinal cord (Prakash, Snook, Lewis, Moti, & Kramer, 2008). This process interferes with the neuronal pathways in the central nervous system and it has been associated with progressively developing motor, sensory, cognitive and psychological deficits (Compston & Coles, 2008).

The following four MS subtypes have been described to categorise disease prognosis and progression patterns: (a) *Relapsing-Remitting,* in which there are unpredictable attacks (relapses) that last for varying periods followed by partial or total recovery (remission); (b) *Primary-Progressive,* which is defined by symptoms that gradually get worse over time; (c) *Secondary-Progressive* characterized by lack of distinct attacks, but with slow onset and steadily worsening symptoms; and (d) *Benign,* when disability resulting from relapsing-remitting MS is either mild or non-existent after a long period (Hurwitz, 2009; WHO, 2006). Each subtype can lead to a range of neurological symptoms, affecting different functions with type and severity widely varying between individuals. The most common presenting symptoms are motor weakness, sensory problems, fatigue, visual disturbances, bladder or bowel problems, pain, and cognitive decline (WHO, 2008).

Driving models

Driving requires an acceptable level of visual, motor, and cognitive function, but few conceptual models of driving have been developed to incorporate the multiple skills associated with this ability (British Psychological Society [BPS], 2001). Michon's (1979) hierarchical model describes three levels of decision making involved in driving.

The highest *strategic* level refers to decisions made regarding planning the driving task, such as the choice of route, the impact of weather conditions, and the time of day to travel. At the *tactical* level, the driver is required to make decisions about handling the vehicle such as the speed and distance from other vehicles. The *operational* level involves common driving motor actions such as braking, steering, or dealing with impending danger. A more recent and interactive model of driving after cerebral damage has been developed by Galski, Bruno, and Ehle (1992) where psychological factors, sensory input, information processing, scanning and attention mechanisms, executive processes, general driving skills, driving experience, and motor function were taken into account. Marshall et al. (2007) formulated a conceptual framework, which combined elements from these two models and described a range of functional abilities that can affect each level of driving behaviour. Figure 1 illustrates this model of driving behaviour. For instance, judgement and insight can influence risk-taking or route planning (strategic) and motor deficits can impact on steering or braking responses (operational). Decision making about manoeuvring a vehicle may be affected by sensory function, visuospatial perception, reasoning skills, driving knowledge or previous experience (tactical).

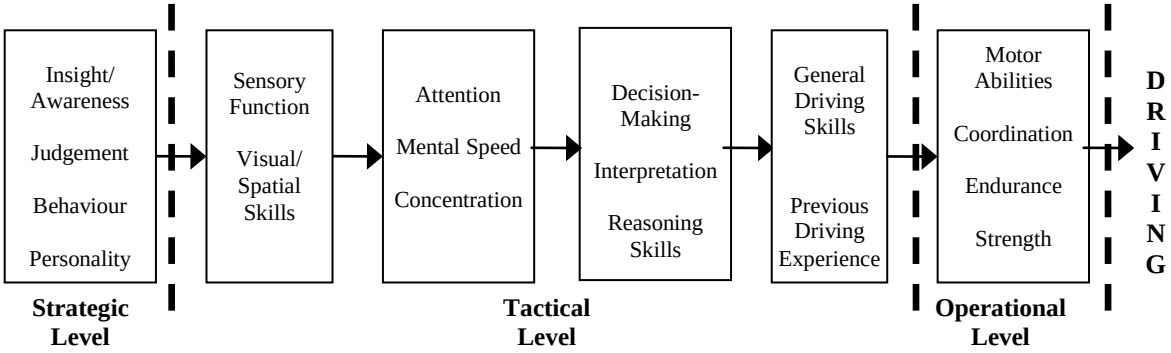

Figure 1. Conceptual framework of driving (adapted from Marshall et al., 2007)

Measuring driving ability

The need for formal assessment of fitness to drive in neurological conditions has been highlighted by driving licensing authorities and healthcare professionals (BPS, 2001). Driving ability in clinical and research practice has been determined using different types of assessments (Ryan et al., 2009). On-road tests, office-based assessments, driving records and caregiver reports have been included in previous reviews in stroke and dementia (Marshall et al., 2007; Reger et al., 2004). On-road tests evaluate driving ability by placing participants behind the wheel of an actual car. The use of on-road assessments is the closest approximation of real-life driving and it is regarded as the 'gold' standard of driving ability. However, utility of on-road tests remains debatable because of reliability and validity limitations (Akinwuntan et al., 2012a). Non-road tests refer to a variety of measures such as driving simulators, tests of driving knowledge, crash and traffic violation records. Office-based tests include paper-and-pencil cognitive assessments that are usually administered by occupational therapists and/or clinical psychologists.

Predicting fitness to drive

Different neurological conditions interact with driving ability in different ways based on the brain structures affected. In acquired and recovering conditions, such as stroke and traumatic brain injury, the extent to which driving competence is compromised depends on the type or severity of deficits which are determined by the location and size of cerebral damage (BPS, 2001). In degenerative and progressive conditions, the fluctuating and unpredictable course of disease patterns complicates procedures for determining fitness to drive (Reger et al., 2004).

The evaluation of fitness to drive in all neurological conditions is based on a wide range of motor, visual, and cognitive factors. There is some evidence that there is a relationship between motor impairment and driving ability (Radford, Lincoln, & Lennox 2004; Stolwyk, Charlton, Triggs, Iansek, & Bradshaw, 2006). Motor deficits may affect steering and braking responses, however car adaptations can be provided to compensate even for significant impairments that can allow severely disabled individuals to drive (Schultheis, DeLuca, & Chute, 2009). Sensory function is assessed using measures of visual acuity, visual field, visual inattention and visual information processing. Most studies tend to exclude individuals with neurological conditions who do not meet legal visual standards for driving (Lincoln & Radford, 2012). According to the BPS (2001) publication on 'Fitness to drive and cognition' different cognitive functions including attention, perception, memory and executive skills have generally been related to on-road driving performance. Several studies have shown a relationship between neuropsychological tests and driving ability in samples with specific neurological conditions and mixed aetiologies, but the predictive validity of individual tests for each cognitive domain remains uncertain (Lincoln & Radford, 2012).

Most studies have been focused on stroke and dementia, so systematic reviews have been conducted on predictors of driving ability in these populations. Marshall et al. (2007) reviewed 17 stroke studies and suggested that cognitive function appears to be the strongest predictor of driving outcomes. Other predictors were also identified such as sensory function and driving knowledge, but these did not provide such strong evidence. Another meta-analysis of 27 studies concluded that cognitive tests predicted fitness to drive after stroke, whereas clinical characteristics, motor and visual deficits did not predict on-road performance (Devos et al., 2011).

Reger et al. (2004) examined the relationship between cognitive assessments and driving ability in people with dementia. Of the 27 studies reviewed, 12 used on-road tests and neuropsychological tests were grouped according to cognitive domains. Effect sizes were small, but significant for the relationship between on-road driving and neuropsychological testing. A moderate association was found between measures of visuospatial skills and non-road tests. Molnar, Patel, Marshall, Man-Son-Hing and Wilson (2006) identified inconsistent findings between dementia studies in terms of the individual cognitive tests associated with driving ability. This review highlighted the limited clinical utility of tests with no available cut-off scores.

Fewer studies on fitness to drive have been conducted in other progressive neurological conditions, such as Parkinson's disease and MS. Klimkeit, Bradshaw, Charlton, Stolwyk, and Georgiou-Karistianis (2009) summarised the literature on the relationship between driving performance and neuropsychological testing, disease status, and medication effects in Parkinson's disease. Ten studies were included that used a combination of different neuropsychological measures to best predict compromised driving ability. It was suggested that visuospatial perception, attention, memory, information processing, and executing functioning skills could affect driving performance in this condition. Although MS is the most common cause of neurological disability in younger adults (Hurwitz, 2009), it is the only neurological condition for which there is not a published narrative or systematic literature review.

Rationale

Research to date suggests that there is still no consensus on to which factors best predict safety to drive in people with neurological conditions. Few studies have been carried out to investigate predictors of driving ability in individuals with MS, so a systematic review of the literature was undertaken to identify the most consistent factors predicting driving performance in this population. Marshall's et al. (2007) model was used to describe skills required for driving and to guide the classification of factors predicting driving ability in MS (Figure 1).

Aim

The aim of this review was to synthesise and critique the literature on predictors of driving ability in people with MS. It explored what factors may be associated with driving performance in this neurological population in order to facilitate the evaluation process of fitness to drive in clinical practice. Attempts were made to address the variability noted in the existing research literature and to identify gaps for future studies in this area.

Methods

Terminology

Key study terms such as driving ability/skill/behaviour and fitness/safety to drive may refer to different levels of the ICF model that was previously described (WHO, 2002). However, they are often used interchangeably to describe an acceptable standard of driving performance. Similarly, the terms *impairment* and *disability* are both used to describe MS severity while in fact they may have different meanings. As the difference in terminology and the dynamic interaction between the above terms is not clarified in the relevant literature, these will be used interchangeably throughout this review.

Search terms

For each database the same search terms were used to identify relevant articles. The following keywords were used individually and in various combinations[1]: "driving* or fitness to drive" AND "multiple sclerosis* or MS". The Boolean operators such as AND, OR were used to combine keywords in order to widen and narrow database searches. The medical subheadings (MeSH) associated with each database were used where available.

Search strategy

The author conducted the literature search according to the recommendations provided by the Cochrane Handbook of Systematic Reviews (Higgins & Green, 2011). The time period of the search ranged from inception of each electronic database until June 2012. Database searches were carried out in MEDLINE (since 1950), PsychInfo (since 1806), CINAHL (since 1982), and Cochrane Database of Systematic Reviews to identify relevant published studies on safety to drive in MS. The citation database Web of Science (since 1981) was also used to supplement this search.

[1] Truncation symbol (*) was placed at the end of search terms to retrieve variations of that keyword.

Three key journals with the highest number of MS related articles were manually searched: *Multiple Sclerosis*, *International Journal of MS Care*, and *Neurology*. Reference lists of included and excluded articles were scanned to ensure that all relevant articles were considered. Papers in press were sought by contacting experts in the field.

Eligibility criteria

All studies that investigated factors associated with driving ability in MS were selected based on a number of inclusion and exclusion criteria. Studies that included both on-road and off-road tests were eligible. Objective and subjective outcome measures of driving performance were also considered (e.g., driving cessation, driving simulators, computerised tests, driving reports). It was decided to exclude studies with weaker design methodology, such as case reports, case series and studies with small sample size ($n \leq 5$). Editorials, dissertation and conference abstracts were also excluded as that they did not provide sufficient information for assessing methodological quality. Eligibility criteria for studies included in this review are presented in Table 1.

Table 1

Eligibility Criteria

Criteria	Inclusion	Exclusion
1	Studies that included participants diagnosed with MS	Studies including mixed group samples (i.e., MS group< 50%) where data for MS participants cannot be extracted
2	Prospective and retrospective cohort, cross-sectional, correlational, case-control, RCT studies	Duplicate articles, case reports, case series, dissertation and conference abstracts, reviews
3	Studies including > five MS participants	Articles published in languages other than English

Data extraction and synthesis

The information collected from articles was critically appraised and synthesised. Data about sample characteristics, study design and key findings were extracted. All factors related to driving ability within each study were identified and were classified according to different categories. As numerous cognitive tests exist that may have specific and different impact on driving ability, it was attempted to group and classify such predictors based on five cognitive domains. Cognitive predictors were categorised into attention, perception, executive, memory and language. Some measures evaluate multiple domains and there may be an overlap, so they were categorised according to the primary cognitive domain. When categorisation was unclear, previous published reviews (Devos et al., 2011; Marshall et al., 2007) and recognised publications (Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006) were used to group neuropsychological tests into cognitive domains.

Methodological quality

Each study reviewed was rated using the Newcastle-Ottawa Scale (NOS; Wells et al., 2009), which has been recommended as a useful quality assessment tool (Deeks et al., 2003). The NOS has been used in systematic reviews on predictors of driving ability in other neurological conditions (Devos et al., 2011; Marshall et al., 2007; Molnar et al., 2006). It allocates a total of nine stars related to selection of participants, comparability of results and quality of outcome measures (Appendix-NOS). The author rated each study to provide a total quality score which was calculated by counting the number of stars. Higher quality was assessed using an additional criterion referring to whether a study used an on-road test as an outcome measure. The quality of each study could range from the lowest score of 0 to 10. Studies that received ratings ≥5 were considered of acceptable quality. Half of the studies were randomly selected and rated by an independent rater. Inter-rater reliability was assessed using intra-class correlation (ICC).

Results

Study selection

A flow chart of the selection process of the included studies is detailed in Figure 2. An attempt was made to include all published studies examining factors related to driving among individuals with multiple sclerosis. The search strategy resulted in a total of 149 references of which 109 were not considered based on the title and abstract. Twenty full-text articles were retrieved and six were excluded because they did not meet the eligibility criteria. A total of 14 studies met the inclusion criteria and were reviewed.

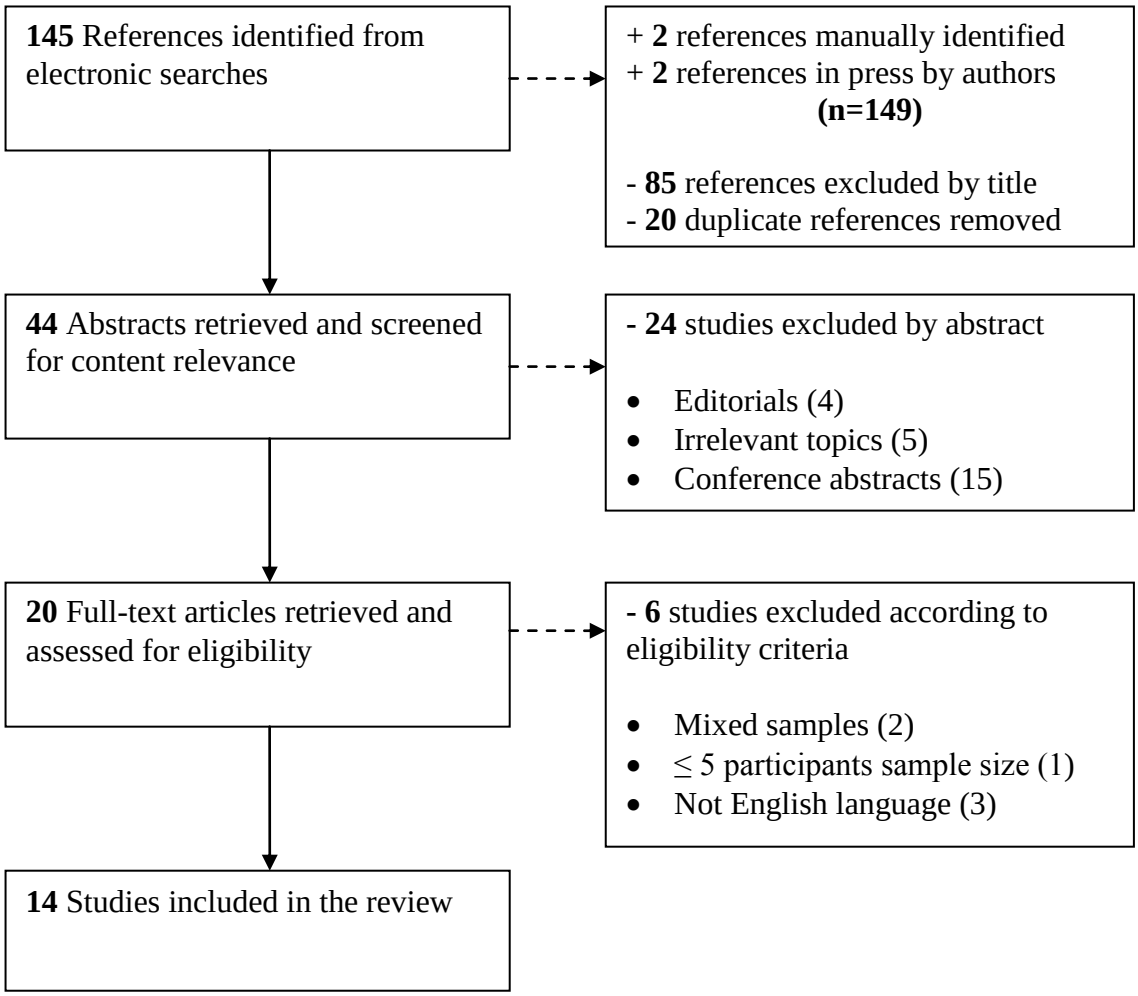

Figure 2. Review and selection of articles

Description of studies

Table 2 summarises the results of the studies included. Methodological quality scores ranged from 3 to 8 (*Mean*=6) and inter-rater agreement was moderate (ICC=.55). Almost half of the studies assessed driving ability based on performance on computerised tests, such as the Useful Field of View and Neurocognitive Driving Test, (Akinwuntan et al., 2012a, 2012b; Schultheis, Garay, & DeLuca, 2001; Shawaryn, Schultheis, Garay, & DeLuca, 2002) and driving simulators (Kotterba, Orth, Eren, Fangerau, & Sindern, 2003; Marcotte et al., 2008). Nine studies relied on documented traffic accident and violation reports as well as self-reported driving behaviours (Chipcase, Lincoln, & Radford, 2003; Lings, 2002; Marcotte et al., 2008; Ryan et al., 2009; Schultheis et al., 2001; Schultheis, Garay, Millis, & DeLuca, 2002; Schultheis, Weisser, Manning, Blasco, & Ang, 2009; Schultheis et al., 2010a; Shawaryn et al., 2002). Only five studies used on-road assessments as the closest measure of driving ability in real-life conditions (Akinwuntan et al., 2012a, 2012b; Lincoln & Radford, 2008; Schultheis et al., 2009; Schultheis et al., 2010b).

Ten studies were conducted in United States and the remaining four in Europe (Denmark, 1; Germany, 1; UK, 2). Sample sizes ranged from 17 to 197 participants and the majority of studies included more participants with relapsing-remitting type of MS. Mean age of participants ranged from 35 to 49 years old with a significantly higher proportion of females. Years since MS diagnosis widely varied across participants with mean disease duration between studies ranging from 5 to 13 years. Most studies were conducted in outpatient and research settings in the community. A number of factors which may influence driving performance in MS were identified and were classified within the following categories: (a) cognitive impairment; (b) sociodemographic characteristics; (c) physical status; (d) sensory function; and (e) driving-related skills. Cognitive impairment and physical status were the most frequently studied factors.

Table 2

Characteristics of Included Studies

Authors, Year, Country[a]	Sample Size	Design, Setting	Outcome Measures	Key Findings	On-road assessment (Yes/No)	Quality Score[b]
[1]Akinwuntan et al. (2012a) USA	MS=44	Cohort Community	BI, EDSS, HADS, MFIS, MMSE, MSFC, ROCF, SDSA, Stroop, TMT-A/B, UFOV, WAIS-III BD and DS	Cognitive and visual deficits predictive of driving performance. No relationship between physical disability and driving ability.	Yes	7 (6)
[2]Akinwuntan et al. (2012b) USA	MS=44	Cohort Community	BI, EDSS, HADS, MFIS, MMSE, MSFC, ROCF SDSA, Stroop, TMT-A/B, UFOV, WAIS-III BD and DS	SDSA battery predictive of on-road performance (86% accuracy, 80% sensitivity, 88% specificity).	Yes	7
[3]Chipchase, Lincoln, & Radford (2003) UK	MS=75 HCs=63	Case-control MS Clinic	Driving Questionnaire, FSS	Fatigue, numbness, leg, bladder and eye problems affected self-reported driving behaviours.	No *Driving Questionnaire*	6
[4]Kotterba, Orth, Eren, Fangerau, & Sindern (2003) Germany	MS=31 HCs=10	Case-control MS Clinic	EDSS, MSFC	Accident rate significantly associated with cognitive impairment. No relationship between physical impairment and driving.	No *Driving Simulation*	5

Table 2 Continued

Authors, Year, Country[a]	Sample Size	Design, Setting	Outcome Measures	Key Findings	On-road assessment (Yes/No)	Quality Score[b]
[5]Lincoln & Radford (2008) UK	MS=34	Cohort Driving Centre	AMIPB, EADL, PASAT, SDSA, Stroop	Women more likely to be unsafe drivers. Cognitive abilities accurately predicting safety to drive.	Yes	7 (6)
[6]Lings (2002) Denmark	MS=197 HCs=545	Case-control Hospital	Emergency hospital admissions following car accident as a driver, ISS	MS drivers at greater risk of road traffic accidents compared to healthy controls.	No *Driving Records*	5(6)
[7]Marcotte et al. (2008) USA	MS=17 HCs=14	Case-control Community	EDSS, GDS (*overall cognitive functioning score*), MAS, MSQLI	Cognitive impairment was the strongest predictor of lane position difficulty and reduced response time in speed changes. Spasticity was significantly associated with reduced accuracy on tracking the lead car.	No *Driving Simulation*	5 (6)
[8]Ryan et al. (2009) USA	MS=78	Case-control Community	AQ, BDQ-Social, Driving survey, EDSS, NP composite (*overall cognitive functioning score*)	Awareness of deficit moderated fitness to drive. Neuropsychological functioning predicting driving status and compensatory driving behaviours.	No *Driving Records*	5

Table 2 Continued

Authors, Year, Country[a]	Sample Size	Design, Setting	Outcome Measures	Key Findings	On-road assessment (Yes/No)	Quality Score[b]
[9]Schultheis, Garay, & DeLuca (2001) USA	MS=28 HCs=17	Case-control Community	UFOV, NDT, MVPT-R, PASAT, TMT, Stroop, WAIS-R BD and DS	MS group with cognitive impairment significantly poorer performance on driving-related skills than the MS group without cognitive impairment and the control group.	No *Computerised Tests, Driving Records*	6
[10]Schultheis, Garay, Millis, & DeLuca (2002) USA	MS=27 HCs=17	Case-control Community	MVPT-R, PASAT, TMT-A/B, Stroop, WAIS-R BD and DS	MS group with cognitive impairment showed increased incidence of crashes and reduced driving frequency.	No *Driving Records*	6 (7)
[11]Schultheis et al. (2010a) USA	MS=66 HCs=26	Case-control Community	Visual acuity, depth, colour perception, EDSS	No significant correlations were found between visual measures and self-reported driving behaviours or documented accident/violation rates	No *Driving Records*	4
[12]Schultheis, Weisser, Manning, Blasco, & Ang (2009) USA	MS=66 HCs=30	Case-control Community	EDSS, DBQ	Greater disease severity accounted for differences in self-limiting driving behaviours and frequency of driving.	Yes *Driving Questionnaire, Driving Records*	7 (8)

Table 2 Continued

Authors, Year, Country[a]	Sample Size, n	Design, Setting	Outcome Measures	Key Findings	On-road assessment (Yes/No)	Quality Score[b]
[13]Schultheis et al. (2010b) USA	MS=66	Cohort Community	EDSS, TMT-B, SDMT, PASAT, MVPT-R, WAIS-Vocabulary, CVLT-II, SPART 7/24	Information processing speed predictive of on-road performance and visuospatial learning/recall predictive of collision and violation frequency	Yes	6
[14]Shawaryn, Schultheis, Garay, & DeLuca (2002) USA	MS=29	Cohort Rehabilitation Centre	MSFC, UFOV, NDT	Functional impairment, cognitive function significantly related to driving skills. Individuals not more prone to committing driving errors but less efficient in responding to stimuli	No *Computerised Tests, Driving Records*	4 (3)

Note. AQ=Awareness Questionnaire; AMIPB=Adult Memory Information Processing Battery; BD=Block Design; DBQ=Driving Behaviour Questionnaire; BDQ-Social=Barriers to Driving Questionnaire-Social Influences; BI=Barthel Index; CVLT=California Verbal Learning Test; DS=Digit Span; EADL=Extended Activities of Daily Living; EDSS=Expanded Disability Status Scale; FSS= Fatigue Severity Scale; HCs=Healthy Controls; ISS=Injury Severity Score; MFIS=Modified Fatigue Impact Scale; MSFC=Multiple Sclerosis Functional Composite; MVPT-R=Motor Free Visual Perception Test-Revised; NDT=Neurocognitive Driving Test; PASAT=Paced Auditory Serial Addition Test, ROCF=Rey-Osterrieth Complex Figure; SDMT=Symbol Digit Modality Test; SDSA=Stroke Driver's Screening Assessment; SPART 7/24=Spatial Recall Test ; TMT-A/TMT-B=Trail Making Test; UFOV=Useful Field of View; WAIS=Wechsler Abbreviated Intelligence Scale

[a] Studies presented in alphabetical order. [b] Methodological quality using the Newcastle-Ottawa Scale plus additional criterion of an on-road test (0-10 total score). The scores of the independent rater are included in brackets.

Cognitive impairment

Ten studies (Akinwuntan et al., 2012a, 2012b; Kotterba et al., 2003; Lincoln & Radford, 2008; Marcotte et al., 2008; Ryan et al., 2009; Schultheis et al., 2001, 2002, 2010b; Shawaryn et al., 2002) examined whether the presence of cognitive impairment influenced driving ability. Most studies attempted to evaluate a broad range of cognitive domains, but only three studies (Akinwuntan et al., 2012; Lincoln & Radford, 2008; Schultheis et al., 2010b) investigated the contribution of specific cognitive factors. Cognitive tests were classified according to cognitive domain, but some tests assessed more than one domain. The most frequently evaluated cognitive domains were attention, perception, executive function and memory. Only one study (Schultheis et al., 2010b) investigated language function. Table 3 summarises the cognitive tests that appear best able to predict driving ability in MS.

The Multiple Sclerosis Functional Composite (MSFC) is a screening measure used to capture information about disease status on three clinical dimensions. The cognitive dimension includes the 3-seconds interval version of the Paced Auditory Serial Addition Test (PASAT), which is a test of auditory information processing speed and sustained attention. Cognition as measured using this version of the PASAT was found to be significantly related to driving performance in three studies (Akinwuntan et al., 2012a, 2012b; Kotterba et al., 2003; Shawaryn et al., 2002).

Schultheis et al. (2010b) reported that the standard PASAT version (including four trials ranging from 2.4-seconds to 1-second interval) was not a significant predictor of driving ability. The Symbol Digit Modality Test was also included in this study as a measure of information processing speed and it only marginally predicted the on-road test performance. However, it was found to be the strongest predictor from a seven-subtest neuropsychological battery. The two standard PASAT trials (2 and 4 seconds interval) and the AMIPB-Information Processing task were used by Lincoln and

Radford (2008), but only the latter was found to significantly differ between participants who passed and failed the on-road test. These two tests theoretically tap similar cognitive abilities, but the AMIPB-Information Processing task may be more relevant for predicting on-road performance as it accounts for motor speed while assessing visual mental processing.

Two studies examined the predictive validity of the Stroke Driver's Screening Assessment (SDSA), which comprises four subtests. The Dot Cancellation subtest assesses attention and the Road Sign Recognition, Square Matrix Directions and Compass subtests assess non-verbal reasoning skills. In the first study by Lincoln and Radford (2008), the Dot Cancellation and Road Sign Recognition subtests were significantly different between participants who passed and failed an on-road test, so these were included in a predictive equation for classifying safe and unsafe MS drivers. Akinwuntan et al. (2012b) assessed the driving performance of 44 participants with relapsing-remitting MS and the SDSA battery accurately predicted (86%) their on-road test performance. Based on the previous study, the predictive validity of individual subtests was assessed and it was recommended that the Road Sign Recognition, Square Matrix and Compass subtests were the strongest SDSA predictors for inclusion in a battery for assessing fitness to drive in MS (Akinwuntan et al., 2012a).

The Useful Field of View (UFOV) is a three-subtest computerised measure which assesses three aspects of visual attention including processing speed, divided and selective attention. Akinwuntan et al. (2012a) has shown that individuals who passed the on-road test performed better on all three subtests. Two studies used the UFOV overall score as an outcome measure of driving rather than cognitive ability because it could classify drivers according to accident risk. For instance, accident risk as measured by the UFOV was significantly associated with the MSFC subtest of cognitive function, but not with other driving measures, such as actual driving records and self-reported

driving behaviours (Shawaryn et al., 2002). This finding was justified as both measures tap information processing speed and attention skills, and therefore they assess similar constructs. Schultheis et al. (2001) reported a relationship between accident risk and the presence of cognitive impairment based on overall neuropsychological performance. It was shown that more individuals with cognitive impairment were classified within the high risk UFOV category compared to healthy controls and those without cognitive impairment.

Two studies (Akinwuntan et al., 2012a; Schultheis et al., 2010b) used the Trail Making Test-B as a measure of executive functioning that can also assess visual attention and speed of processing, but it was not found to be significantly associated with driving abilities.

Four studies used a range of cognitive tests to calculate neuropsychological profile scores and to assess overall cognitive function of participants with MS compared to matched healthy controls (Marcotte et al., 2008; Ryan et al., 2009; Schultheis et al., 2001, 2002). These studies found that MS participants with cognitive impairment performed worse on driving measures compared to those participants without cognitive impairments and healthy controls, so it was only concluded that the mere presence of cognitive impairment negatively influences driving ability.

Table 3

Cognitive Tests Predicting Driving Ability by Cognitive Domain

Predictors [a]	**On-road Assessment**	**Driving Simulators/ Computerised Tests**	**Driving Reports/ Questionnaires**
Attention and Concentration			
AMIPB-Information Processing (Adjusted)	p=**.02**/**.04**[5]	–	–
PASAT-MSFC version	p=**.003**[1,2]	p<**.05**[4];**p<.05**[14]	p>.05[14]
PASAT-Standard version	p=.88[13];p=.23/.36[5]	–	–
SDMT	p=.07[13]	–	p=.95[13]
SDSA-Dot Cancellation (False Positives)	p=**.04**[1,2];p=**.004**[5]	–	–
UFOV	p=**.003**/**.008**/**.006**[1]	***p*<.01**[14]	p>.05[14]
WAIS-Digit Span	p=.65[1]	–	–
Visuospatial Perception			
AMIPB/ROCF-Complex Figure Copy	p=.47[1,2];p=**.04**[5]		–
MVPT-R	p=.59[13]		p=.10[13]
SPART 7/24	p=.70[13]		p=.06[13]
WAIS-Block Design	p=.11[1]		–
Executive and Reasoning Skills			
SDSA-Compass	p=**.002**[1,2];p=.15[5]		–
SDSA-Directions	p=.07[1,2];p=.34[5]		–
SDSA-Road Sign	p=**.009**[1,2];p=**.005**[5]		–
Stroop Colour-Word Test	p=.35[1];p=.26[5]		–
Trail Making Test-B	p=.08[1];p=.85[13]		p=.69[13]

Table 3 Continued

Memory		
AMIPB-Design Learning	*p*=.22/.32/**.03**[5]	_
AMIPB-List Learning	*p*=.26/.21/.33[5]	_
AMIPB-Story Recall	*p*=.48/.35[5]	_
CVLT-II	*p*=.67[13]	*p*=.15[13]
Language		
WAIS-Vocabulary	*p*=.37[13]	*p*=.87[13]

Note. Superscript numbers indicated study reference number from Table 2.
[a] Data of statistical significance were extracted where available for each type of driving measure. ***p*<.05, ****p*<.01, *****p*<.001.**

Sociodemographic characteristics

Data were collected on a range of sociodemographic characteristics that may be linked with driving outcomes. Lincoln and Radford (2008) demonstrated that there was a significant gender difference between drivers with MS who passed and failed the on-road test. It was suggested that women were more likely to be unsafe drivers than men. However, this finding did not seem to be related to a significant difference in years of driving experience or time since last driven between women and men participants. Other studies (Akinwuntan et al. 2012a; Ryan et al., 2009) have failed to show any gender differences in driving outcomes, but these samples have recruited a significantly higher proportion of female MS participants. Ryan et al. (2009) reported no significant differences on demographic variables (i.e, age, gender, education, income) between MS participants currently driving and those that have voluntarily stopped driving. Similarly, Akinwuntan et al. (2012a) showed that demographic variables did not significantly differ between participants who passed or failed an on-road test.

Physical status

Ryan et al. (2009) found that shorter illness duration was significantly related to driving status, as these individuals were more likely to continue driving, but not related to driving safety. This finding is consistent with other studies reporting that illness duration was not associated with driving outcomes (Akinwuntan et al., 2012a; Lincoln & Radford, 2008; Shawaryn et al., 2002).

Eight studies assessed severity of physical disability using the Expanded Disability Status Scale (EDSS), which is based on neurological examination of functional systems. EDSS scores could range from 0 (mild)-10 (severe) and mean scores between studies were mild to moderate. Schultheis et al. (2009) suggested that moderate impairments as measured by the EDSS may indicate changes in self-reported driving behaviours and on-road driving performance. A strong relationship was found between EDSS and

whether people with MS continue to drive, but a weaker relationship with accident frequency (Ryan et al., 2009). Other studies did not report significant findings between EDDS and driving ability (Akinwuntan et al., 2012a; Kotterba et al., 2003).

Four studies included the MSFC as a measure of functional impairment that can provide more information than the EDSS about overall disease status. The 9-Hole Peg Test (9-HPT) and the Timed 25-feet Walk Test (T25W) are the two clinical dimensions of the MSFC that assess arm-hand function and leg-ambulation function respectively. Kotterba et al. (2003) reported that accident frequency during a driving simulator test was not correlated either with the T25W or 9-HPT subtests. Another study by Shawaryn et al. (2002) also found that both subtests were not significantly related to self-report and official driving records, but the hand function subtest (9-HPT) was significantly related to the latency scores of a computerised driving test. Similarly, Akinwuntan et al. (2012a, 2012b) suggested that the T25W subtest was not significantly associated with on-road performance, but the 9-HPT subtest differentiated between safe and unsafe MS drivers. Independence on leisure and self-care activities of daily living was also not significantly associated with on-road driving performance as measured by the Extended Activities of Daily Living (Lincoln & Radford, 2008) and the Barthel Index (Akinwuntan et al. 2012a, 2012b).

Two studies assessed fatigue using different outcome measures. Specifically, Chipchase et al. (2003) concluded that fatigue has a significant effect on driving ability using the Fatigue Severity Scale (FSS) and a questionnaire to assess driving competence. It was shown that the MS group restricted or adapted their driving behaviours more than the control group. Other physical factors such as numbness, eye, leg and bladder problems were also shown to equally affect ability to drive. Cut-off scores on the FSS were identified to determine the severity of fatigue that could affect driving.

Nevertheless, Akinwuntan et al. (2012a) examined fatigue using the Modified Fatigue Impact Scale and it found no association between fatigue severity and on-road driving performance. Inconsistent findings between these studies may be attributed to differences in design, sample characteristics, and measures used for assessing fatigue and driving ability.

Marcotte et al. (2008) examined the contribution of spasticity to MS-related disability and driving tasks. Spasticity as measured by the Modified Ashworth Scale was not a strong predictor of driving performance, but it was associated with worse pedal performance while changing and maintaining speed during driving simulator conditions. However, this study had a small size and excluded participants who have stopped driving or were physically unable to use the simulator.

Sensory function

People with MS can be affected by different kinds of temporary or persistent visual impairments, including loss of visual acuity, colour perception deficiency, blurred or double vision. Across studies, sensory function was assessed using different tests of visual performance. The range of visual skills assessed was restricted as studies that included an on-road assessment recruited suitable participants based on the minimum legal requirements of visual acuity and peripheral vision established by the relevant driving authorities (Akinwuntan et al., 2012a).

Schultheis et al. (2010a) study examined exclusively the relationship between objective tests of visual function and driving performance. The findings supported that MS participants with self-reported visual difficulties performed worse on a test of colour perception, but not on tests of depth perception and visual acuity when compared to MS participants with no self-reported visual difficulties and healthy controls. These results were not in relation to an on-road test as measures of driving performance were restricted to self-reported driving behaviours and documented accident/violation rates.

Furthermore, the study only used visual quantity measures, such as acuity and depth perception rather than visual quality measures, such as contrast sensitivity.

Although colour perception did not significantly correlate with measures of driving performance in the previous study, more recently Akinwuntan et al. (2012a) have suggested that a visual test of blue and violet colour perception can distinguish MS participants who pass versus those who fail an on-road assessment. The study identified a moderate association between additional visual tests including glare recovery and contrast sensitivity.

Driving-related skills

Most studies used a range of driving-related variables via self-report or official records to assess driving ability. Only two studies investigated driving-related skills as predictors of on-road performance. Driving experience and daily driving distance were not significantly associated with on-road test outcomes (Akinwuntan et al., 2012a), but were significantly associated with greater time since last driven a car (Lincoln & Radford, 2008). These two studies identified the SDSA Road Sign Recognition subtest as a significant cognitive predictor of driving ability. This is a subtest of executive skills, but it also assesses driving knowledge and offers ecological validity in the assessment of driving. Therefore, road sign knowledge is a driving-related skill predictive of safe versus unsafe drivers.

Lings (2002) assessed safety to drive in people with MS based on records of accident frequency. It was suggested that a greater number of emergency hospital admissions and severity of injuries were associated with a greater risk of traffic accidents in individuals with MS compared to healthy matched controls. Table 4 summarises remaining predictors of driving ability.

Table 4

Additional Factors Predicting Driving Ability by Category

Predictors [a]	**On-road Assessment**	**Driving Simulators/ Computerised Tests**	**Driving Reports/ Questionnaires**
Sociodemographic Characteristics			
Gender	p=1.00[1];p=**.03**[5]	p>.05[14]	
Age	p=.89[1];p=.09[5]	–	
Type of MS	–	–	
MS duration	P=.10[1];p=.26[5]	p>.05[14]	p<**.01**[8]
Physical Status			
• **Disability**			
Barthel Index	p=.52[1]	–	–
EDSS	p=.75[1];p<**.001**[12]	p>.05[4]	p=**.04**/.07[8];p= **.01**[12]
EADL	p=.44[5]	–	–
MSFC composite score	p=.14[1]	***p*<.05**[4];***p*<.05**[14]	***p*<.05**[14]
• **Motor functioning**			
MSFC Timed 25-Foot Walk	p=.13[1]	p>.05[4];p>.05[14]	p>.05[14]
MSFC 9-Hole Peg Test	p=**.04**[1]	p>.05[4];***p*<.05**[14]	***p*<.05**[14]
• **Fatigue**			
MFIS	p=.55[1]		–
FSS	–		p<**.001**[3]
• **Spasticity**			
MAS		p<**.05**/**.04**[7]	

Table 4 Continued

Sensory Function			
Visual field	_		_
Visual acuity	_		p=.06/.48[11]
Depth perception	p=.66[1]		p=.19/.33[11]
Colour perception	p=**.03**/p=0.13[1]		p=.28/.39[11]
Contrast sensitivity	p=.41[1]		_
Driving-related skills			
Accident/hospital admission frequency	_	p<**.001**[4]	p=.04[6]
Violation/traffic offence frequency	_		p=**.01**[10]
Driving experience (years)	p=.91[1];p=.17[5]		_
Driving frequency (after MS)	_		p<**.01**[10];p<**0.05**[12]
Driving distance	p=.43[1]		_
Time since driven	p=**.02**[5]		_
Driving knowledge (road sign)	p=**.009**[1];p=**.005**[5]		_

Note. Superscript numbers indicated study reference number from Table 2.
[a] Data of statistical significance were extracted where available for each type of driving measure. ***p*<.05, ****p*<.01, *****p*<.001.**

Discussion

The primary goal of this review was to identify determinants of driving ability in people with MS. Twelve of the reviewed studies received ratings of 5 or higher on the NOS, which indicates good quality. A wide range of factors were investigated for evaluating or predicting real-world driving performance in MS. These included office-based assessments (e.g., cognitive, physical, motor, sensory), tests of specific driving knowledge (e.g., traffic sign recognition), and self or proxy reports (e.g., compensatory driving behaviours). However, many of these factors have not been found to reliably and consistently predict driving ability. Inconclusive findings between studies made it difficult to draw definite conclusions about which physical, cognitive, sociodemographic, and driving-related variables are related to driving skills. Differences in sample sizes, driving performance measures, cognitive tests, severity and type of MS-related symptoms may have contributed to these inconsistencies.

Predictors of driving ability in MS

The most common predictors investigated were those related to cognitive function. Akinwuntan et al. (2012a, 2012b) and Lincoln and Radford (2008) concluded that the SDSA can be used as an accurate and sensitive cognitive measure for predicting on road performance in MS. Across the two studies, participants who failed the on-road test had significantly worse scores on the SDSA Dot Cancellation false positives and Road Sign Recognition tasks. However, both these study samples may be unrepresentative as they did not recruit participants with severe physical disabilities. They also recruited a small number of participants for the large number of variables examined in their analyses which increased the possibility of chance findings.

Many studies used a combination of cognitive tests to best predict driving performance. The cognitive domain more frequently explored in relation to driving abilities was attention. This review revealed that attention and information processing

subtests were related to driving outcomes and this finding is consistent with reports that deficits on such tasks are common and predictive of overall cognitive dysfunction in MS (Chiaravalloti & DeLuca, 2008). Moreover, visuoperceptual and executive functions were associated with measures of driving ability. A review by Klimkeit et al. (2009) reported similar findings regarding which cognitive domains are likely to affect driving ability in people with Parkinson's disease.

Physical status and MS-related disabilities were assessed using a wide range of measures. Most studies did not report significant findings on measures of disease severity, functional independence in daily activities, fatigue and spasticity. EDSS was the most common disability measure but despite being widely used in MS studies, it has been critisised for focusing on ambulatory function and failing to capture other functional impairments (Thompson & Hobart, 1998). All studies included participants with mild to moderate levels of ambulatory function (EDSS≤7), which may limit the generalisability of their findings. Disease severity did not reliably predict driving behaviours. However, such findings may be limited by the restricted range of study samples as they generally included people with milder physical disabilities and a higher degree of functional independence.

Although sensory function is commonly affected in MS, visual problems were not significantly associated with driving skills. This finding highlighted an important clinical issue as visual acuity is the most common measure for assessing fitness to drive. Some studies only included individuals who met the minimum visual requirements based on the legal driving standards. Therefore, individuals with significant visual deficits may have been excluded from these samples. However, visual information processing speed was found predictive of on-road performance (Akinwuntan et al., 2012a; Lincoln & Radford, 2008; Schultheis et al., 2009), which has also been found to be an important predictor of driving ability in other progressive neurological conditions

(Uc et al., 2006). Although contrast sensitivity has been found predictive of driving safety in people with Parkinson's disease (Devos et al., 2007; Uc et al., 2009), only a moderate association was found in people with MS (Akinwuntan et al., 2012a).

Overall, studies failed to show any age and/or gender differences in driving outcomes. The difference in gender distribution between MS participants with a greater number of female participants may have influenced study findings. No other significant findings were reported regarding sociodemographic characteristics.

Driving-related characteristics, such as accident and traffic violation frequency, were investigated both as determinants of fitness to drive and as measures of driving ability. There was some evidence that road sign knowledge is a predictor of on-road performance in MS, which is consistent with findings reported in systematic reviews in stroke (Devos et al. 2011; Marshall et al., 2007).

Methodological considerations

Most research on MS and driving was conducted by the same group of researchers (i.e., Schultheis and colleagues). It was difficult to ascertain based on the information available in the papers whether findings reported were part of larger studies or the secondary analyses of original research. Moreover, there were methodological differences between studies including variability in participant characteristics, driving measures, and cognitive assessments. Similarly, reviews on predictors of driving ability in other neurological populations struggled with data synthesis due to wide variability between studies (Klimkeit et al., 2009; Reger et al., 2004). Cognition has been shown to be associated with on-road performance, but cognitive predictors identified depend on the measures selected. A variety of cognitive tests were used between studies and some tests tap more than one domain of cognitive functioning.

There was wide variability in driving measures and a minority of the studies used an on-road test (Akinwuntan 2012a, 2012b; Lincoln & Radford, 2008; Schultheis et al., 2009, 2010b). Although the on-road assessment is a well-recognized evaluation method for assessing fitness to drive, its accuracy has yet to be determined. The 'gold standard' of driving ability has several limitations including scoring subjectivity between assessors and inability to control road traffic variables, which may increase error in on-road test results and decrease its strength with neuropsychological testing (Reger et al., 2004).

An independent rater assessed the methodological quality, but not the eligibility of papers reviewed. Publication and selection bias may have been potentially introduced in the process of study selection, as for example non-English and mixed sample studies were not included.

Despite these limitations, this is the first review to summarise the available literature on MS and driving for guiding clinical decision making and identifying areas for further research. It was structured by a comprehensive driving model previously used to systematically review predictors of driving ability in stroke (Marshall et al., 2007). Predictors were classified under the components of this model which facilitated data extraction and synthesis. It was attempted to address the variability in methods used between studies by categorising type of driving measures and grouping cognitive tests according to cognitive domain. The use of methodological quality and inter-rater reliability aimed to reduce the risk of bias. NOS as a quality assessment tool has shown acceptable inter-rater reliability, criterion and face validity compared to other widely used tools (Hootman, Driban, Sitler, Harris, & Cattano, 2011). Although it has been used by all systematic reviews in this area, it does not specifically address all methodological issues.

Theoretical and clinical implications

When the findings of this review are presented in relation to the conceptual driving model by Marshall et al. (2007), it appears that there are multiple factors that may be related to driving ability in people with MS. The strongest evidence was in relation to cognitive impairment negatively influencing driving outcomes. This was consistent with findings in other progressive neurological conditions (Klimkeit et al., 2009; Reger et al., 2004). However, although some cognitive tests may be accurate enough to make initial recommendations about safety to drive, further studies are needed to assess their validity, reliability and clinical utility for predicting on-road performance. From a practical perspective road sign knowledge and changes in driving behaviours could influence driving outcomes, but may also be dependent on other factors such as cognition and awareness of deficits. There were aspects of the driving model that were either not sufficiently addressed by evidence reviewed, such as personality characteristics, or provided inconsistent findings, such as sociodemographic and disease characteristics.

Physical impairment and visual deficits are often the most common or the only measures used in medical reports for assessing fitness to drive in neurological conditions (Schultheis et al., 2010a). However, this may be problematic in people with MS because studies have not consistently demonstrated a strong relationship between such deficits and driving performance.

A combination of cognitive tests which tap several cognitive domains were identified and these could be considered by clinicians when assessing fitness to drive in people with MS. Predictive equations developed by Akinwuntan et al. (2012a, 2012b) and Lincoln and Radford (2008) could be used when deciding when to refer individuals for an on-road assessment and/or as part of the overall driving evaluation process. The SDSA and the MSFC can be used as quick, simple and easily accessible screening

cognitive measures. The SDSA has been shown to be predictive of on-road performance in several neurological conditions including stroke (Devos et al., 2011), Parkinson's disease (Devos et al., 2007; Radford et al., 2004) and dementia (Lincoln, Radford, Lee & Reay, 2006; Lincoln, Taylor, Vella, Bouman, & Radford, 2010). This review identified very few studies that provided cut-off or classification criteria that could be used to make clinical recommendations. Similar conclusions have been drawn by reviews in dementia and in Parkinson's disease (Klimkeit et al., 2009; Molnar et al., 2006).

Future research

It was shown that studies examining the role of cognition and safety to drive in MS using an on-road assessment tended to be of higher methodological quality. Cognitive abilities were studied more frequently and provided stronger evidence for identifying unsafe drivers than other factors. Specific tests, such as the SDSA and MSFC have been found predictive of driving ability by studies of varying methodological quality. The predictive equations of driving ability in MS developed by Akinwuntan et al. (2012a, 2012b) and Lincoln and Radford (2008) require further validation in independent and more representative samples. Methodological differences in the area of driving and MS were identified and highlighting this issue could help researchers to design better-quality studies in the future. This review did not identify any published studies that investigated the validity of neuropsychological batteries currently used in specialist driving centres as part of their overall evaluation, such as the Rookwood Driving Battery (RDB; McKenna, 2009). The RDB has been developed for assessing driving ability in any neurological condition. Future studies could examine its validity against assessments that have been specifically designed or found predictive of on-road ability in people with MS. Clearly, there is a need for conducting further research on cognitive tests for assessing fitness to drive in this population.

Conclusions

The objective of this review was to identify the most consistent predictors of driving ability in MS. Driving is a complex activity that involves the interaction between physical and cognitive variables. There is some evidence in the literature that a range of factors could predict safety to drive in people with MS. It was indicated that cognitive assessments could make a significant contribution in accurately predicting fitness to drive in this population. Methodological limitations, wide variability of methods used and inconsistent findings between studies were highlighted. Tentative conclusions were made on predictors that could guide the decision-making process for driving competence in MS. Findings highlighted the need for further studies to inform current clinical and research practice.

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Footnotes

[1] Truncation symbol (*) was placed at the end of search terms to retrieve variations of that keyword.

Section Two: RESEARCH REPORT

Validation of Two Neuropsychological Batteries for Assessing Fitness to Drive in People with Multiple Sclerosis

Abstract

Objectives. This study aimed at investigating the concurrent validity of the Multiple Sclerosis Driver's Screening Assessment (MSDSA) and the Rookwood Driving Battery (RDB) for assessing fitness to drive in multiple sclerosis.

Design. Cross-sectional cohort study.

Methods. Twenty-nine participants with MS (mean age=49 years, *SD*=8.37) were recruited from a wide range of settings and completed the MSDSA and RDB in the community. The classifications of the two neuropsychological batteries were compared.

Results. MSDSA and RDB classified twenty-four participants (83%) as safe to drive. There was moderate inter-rater agreement between MSDSA and RDB *pass/fail* classifications (κ=0.53, p<.001). The MSDSA showed 100% sensitivity for *fail* classifications and 89% specificity when compared against the RDB. The MSDSA total score significantly correlated with the Road Sign Recognition (p<.001) and Information Processing (p<.01) MSDSA subtests, but only Road Sign Recognition was predictive of MSDSA outcome. Visual Es-Fs (attention and visual perception) and Comprehension (verbal and executive skills) RDB subtests were predictive of cognitive impairment and accounted for almost 60% of the variance in RDB total scores. Clinical characteristics of MS were not significantly correlated with MSDSA and RDB outcomes.

Conclusions. There is good agreement between MSDSA and RDB *pass* classifications. The MSDSA was better at identifying unsafe participants compared to the RDB. The Road Sign Recognition was more accurate in predicting MSDSA *pass* rather than *fail* classifications (92% sensitivity for pass, 40% specificity). MSDSA and RDB subtests assessing attention, visuospatial perception and executive function skills appear to be related to driving ability in individuals with MS.

Validation of Two Neuropsychological Batteries for Assessing Fitness to Drive in People with Multiple Sclerosis

Driving is an important activity of daily living that is associated with increased independence and community integration (Rapport, Bryer, & Hanks, 2008). Loss of driving ability is associated with poorer quality of life and increased susceptibility to depression (Novack et al., 2010; Marotolli et al., 1997). Driving is a complex task that requires multiple cognitive, physical and behavioural skills. Manoeuvring a car in space and driving in traffic conditions carries an inherent risk, so accidents frequently occur because of driver error or misjudgement. There is some evidence that the functional limitations caused by either acquired or progressive neurological conditions can affect individuals' driving performance to an extent which leads to an increased car-crash risk when compared to healthy matched controls (Meindorfner et al., 2005; Molnar, Patel, Marshall, Man-Son-Hing, & Wilson, 2006; Schanke, Rike, Molmen, & Osten, 2008).

Multiple Sclerosis

Multiple Sclerosis (MS) is a chronic progressive neurological condition which is associated with physical, cognitive, and psychological impairments. It is one of the most common neurological disorders and causes of disability in young and middle-aged adults worldwide (World Health Organisation [WHO], 2008). In the UK, it is estimated that there are around 100,000 people diagnosed with MS (MS Society, 2009).

Individuals with MS can suffer a wide range of neurological symptoms including sensory changes, muscle weakness, fatigue, bladder or bowel difficulties as well as problems with coordination, balance, speech, swallowing, and vision. The condition progresses at different rates across individuals and there are four distinct patterns of disease progression. *Relapsing-Remitting* subtype affects 80% of individuals with MS and is characterized by unpredictable attacks followed by periods of remission with no disease activity. *Secondary-Progressive* MS affects around 65% of those with relapsing-

remitting MS, who then begin to have progressive neurological decline between acute attacks without any periods of remission. *Primary-Progressive* subtype describes 10–15% of individuals and is characterized by progression of disability from the onset, with only minor or no remissions. *Benign* subtype refers to a form of relapsing-remitting MS with mild deficits that recover between relapses (Compston & Coles, 2008; Lobeck, 2002).

Amongst the most devastating MS symptoms are cognitive impairments with studies reporting prevalence rates ranging from 40-70% of individuals suffering from some type of cognitive difficulty at any stage of the condition (Chiaravalloti & DeLuca, 2008). Common cognitive impairments in individuals with MS affect aspects of attention, information processing, memory, visuospatial perception, and abstract reasoning, whereas recognition memory, general intelligence, and language usually remain unaffected (Rogers & Panegyres, 2007).

Fitness to drive

Whilst drivers diagnosed with a neurological condition may be at a higher car-crash risk, fitness to drive should be viewed from a broader and more balanced perspective considering the practical and social benefits of keeping drivers with neurological disabilities on the road without being a risk to themselves and the public.

Driving regulations for resuming or continuing to drive following the diagnosis of a neurological condition vary between countries. In the UK, people diagnosed with acquired and progressive neurological conditions are legally required to inform the Driver and Vehicle Licensing Agency (DVLA). Recommendations for neurological conditions are summarised in the ‘At a glance guide to the current medical standards of fitness to drive’ (Drivers Medical Group, 2012). People with MS may be allowed to continue driving after their initial diagnosis and issued limited licences for up to 1, 2 or 3 years depending on medical review of their condition.

Clinicians need to be aware of the official guidance in order to advise patients of their responsibilities to notify DVLA. Although DVLA holds statutory responsibility for making decisions about license-holding, almost 90% of cases are based on medical reports (British Psychological Society [BPS], 2001). The process relies heavily on information from clinicians who have a duty of care to disclose information in the patient and public interest when the extent and severity of relevant conditions may compromise road safety. However, cognitive deficits are particularly difficult and more complicated to evaluate in relation to driving skills due to variations in clinical judgement, different perceptions among clinicians about the impact of such deficits and the lack of agreement between assessment methods (BPS, 2001).

Neuropsychological testing and driving

Driving skills depend on multiple factors among which are automatic and unconscious processes that rely on intact neuropsychological systems. It is recognised that inattention, distractibility, poor memory, lack of insight and difficulties with multi-tasking are among the cognitive impairments likely to affect driving performance, and therefore these could compromise an individual's safety to drive (BPS, 2001).

It is essential to determine when cognitive function is compromised in people with MS to the extent that this may affect their driving safety, so that they are referred for a formal in-car assessment (Schultheis, Weisser, Manning, Blasco, & Ang, 2009). Neuropsychological assessments will not always accurately differentiate safe from unsafe drivers, but they could be used by clinicians and driving experts as part of the overall evaluation of a driver (BPS, 2001). Neuropsychological testing aims to complement rather than to replace the on-road testing, but it has increasingly become a popular alternative in specialist driving assessment centres (McKenna & Bell, 2007). On-road assessments are expensive, time-consuming and often anxiety provoking for people with neurological conditions (Bhalla, Papandonatos, Stern, & Ott, 2007), so it is

important to identify well validated screening tests that can be used to determine safety to drive. However, there is a lack of consistency in the methods used for assessing cognitive abilities in relation to driving and their interpretation (BPS, 2001). Psychologists in the UK frequently use neuropsychological testing to make recommendations about driving in neurological conditions, but almost 50% of them reported not being very confident and concerned that there is little knowledge about the relationship between cognitive testing and fitness to drive (Christie, Savill, Buttress, Newby, & Tyerman, 2001).

Neuropsychological batteries have been compiled to assess various cognitive domains and studies have explored the relationship between cognition and on-road ability. Some studies have included samples with specific neurological conditions and others with mixed aetiologies. For instance, the Rookwood Driving Battery (RDB; McKenna, 2009) is a 12-subtest neuropsychological battery which has been specifically developed in individuals with a wide range of cerebral pathology aetiologies. Two validation studies were carried out that compared RDB results with the outcome of an on-road assessment. In the first validation study, the test results of 142 clients referred to a specialist driving centre identified unsafe drivers with 71% *sensitivity*[1] for passing and 92% *specificity* for failing the on-road assessment (McKenna, Jefferies, Dobson, & Frude, 2004). The second validation study in a larger sample of 543 clients (McKenna & Bell, 2007) confirmed its theoretical and predictive validity while also providing clinically useful cut-off points to detect people who are likely to fail an on-road assessment. However, this sample only included 13 people with MS. The decision about passing or failing the on-road test was not made blind to the RDB results, so its predictive accuracy may have been lower if this decision had been made independently.

[1]*Sensitivity* is the proportion of true positives and *Specificity* is the proportion of true negatives that are correctly identified by a test (Altman & Bland, 1994).

Cognitive predictors of driving ability in MS

The importance and impact of cognitive factors in determining one's ability to drive has been established in other neurological populations, but it has only recently been documented in MS. Evaluation of driving performance in MS has focused on the impact of a wide range of socio-demographic, physical and driving-related factors, however it has also emphasised the role of cognitive abilities (Schultheis, Garay, & DeLuca, 2001). Cognitive problems seem to be equally or even more important than the physical limitations of MS in relation to driving performance (Shawaryn, Schultheis, Garay, & DeLuca, 2002). Although crash rates in people with MS tend to be higher than in healthy matched controls (Lings, 2002; Schultheis, Garay, Millis, & DeLuca, 2002), it may be a reflection of cognitive impairment rather than the physical aspects of the neurological condition. Schultheis et al. (2002) found that people with MS and cognitive deficits had more car crashes than those without cognitive deficits.

Many studies have examined the role of cognitive predictors in relation to an on-road test in other neurological conditions, but only three studies have been identified in people with MS. Schultheis et al. (2010) assessed 66 individuals with MS on tests of executive functioning, information processing, visual perception, language, and memory. The Symbol Digit Modalities Test, which assesses information processing, marginally predicted on-road driving performance and the Spatial Recall Test, which assesses visuospatial memory, marginally predicted self-reported car incidents. A regression model classified safe and unsafe participants based on these measures with 84% accuracy, but with low sensitivity (25%) and high specificity (98%) for predicting fails on the on-road test. This indicated that these measures could be used to identify those who are safe to continue driving and those who fail would be recommended for an on-road assessment.

Another study by Lincoln and Radford (2008) assessed 34 people with MS on a range of cognitive tests which were compared against the outcome of an on-road test conducted by a driving instructor blind to the results of the assessments. The Multiple Sclerosis-Driver's Screening Assessment (MSDSA) was proposed based on a *pass/fail* equation for predicting on-road performance. Four tests of attention (Dot Cancellation), executive functioning (Road Sign Recognition), visual memory (Design Learning) and information processing (Information Processing-Adjusted) were predictive of safe versus unsafe MS drivers. A discriminant function analysis resulted in a predictive equation with an accuracy of 88% (sensitivity for pass 90%, specificity 90%).

More recently, Akinwuntan et al. (2012b) investigated the accuracy of the Stroke Driver's Screening Assessment (SDSA) to predict on-road performance of 44 individuals with relapsing-remitting MS. The SDSA is a 3-subtest battery that included only two of the MSDSA subtests (Dot Cancellation and Road Sign Recognition). A new equation was developed that better predicted the on-road test compared to the original SDSA equation with 86% accuracy, 80% sensitivity for fail, and 88% specificity.

Rationale

Research evidence on cognitive assessments for predicting fitness to drive in people with MS is sparse. The RDB is a generic and widely used screening measure originally designed and clinically used to assess fitness to drive in any neurological condition. This battery claims that core cognitive skills required for driving do not need to be specific for different neurological groups. Although it has been validated in a large sample of individuals with acquired and progressive neurological conditions, this included few people with MS (n=13). On the other hand, the MSDSA was specifically developed for predicting driving abilities in MS, but it needs further validation in an independent sample. Therefore, it would be theoretically and clinically useful to assess the concurrent validity of the RDB against the MSDSA.

Aims

In order to consider the validation of the RDB and MSDSA as well as the role of factors that may be associated with neuropsychological performance for assessing fitness to drive in MS, the aims of the study were:

1) To investigate the level of agreement for assessing fitness to drive in people with MS between the RDB and MSDSA *pass/fail* classifications.
2) To explore to what extent individual cognitive subtests are associated with the overall performance on each of the two neuropsychological batteries.
3) To compare the demographic, clinical and driving-related characteristics of participants according to MSDSA and RDB classifications and overall scores.

Hypotheses

Following on from these aims, these hypotheses were formulated:

1) The two neuropsychological batteries will show *very good* level of agreement for assessing fitness to drive in people with MS (κ=0.80-0.90, p<.05).
2) Individual cognitive subtests from each of the two neuropsychological batteries will be able to predict either *pass/fail* classifications or overall scores.
3) Clinical variables (i.e., MS type, severity, duration) will not be significantly related to MSDSA and RDB outcomes.

Methods

Design

This study was a prospective quantitative design to compare two neuropsychological batteries for assessing cognitive abilities related to fitness to drive in people with MS. All participants were assessed on the MS-Driver's Screening Assessment (MSDSA) and the Rookwood Driving Battery *(*RDB).

Participants

Individuals with MS at any stage after their diagnosis were invited to take part between December 2011 and July 2012. Appropriate participants were identified via a wide range of MS healthcare professionals across two sites and the recruitment process was coordinated by the author.

Inclusion and exclusion criteria

Participants were included in the study if:

-They had a documented clinical diagnosis of Multiple Sclerosis.

-They agreed to take part and signed a consent form.

-They lived within a 20 miles radius from each recruitment site for practical reasons.

-They had been driving at any point during the past three years.

Participants were excluded from the study if:

-They were not English speakers as all assessments are developed and administered in the English language.

-They were unable to complete any of the two neuropsychological tests due to blindness, profound hearing problems or severe communication difficulties.

A mixed recruitment strategy via clinicians and MS clinics aimed to recruit a representative sample of drivers with MS. A total of 30 participants were recruited, but one individual decided to drop-out before completing study measures. Of the 29 participants who completed assessments, sixteen participants were recruited from Sheffield and thirteen participants from Nottingham. Recruitment rate across sites is shown in Figure 1.

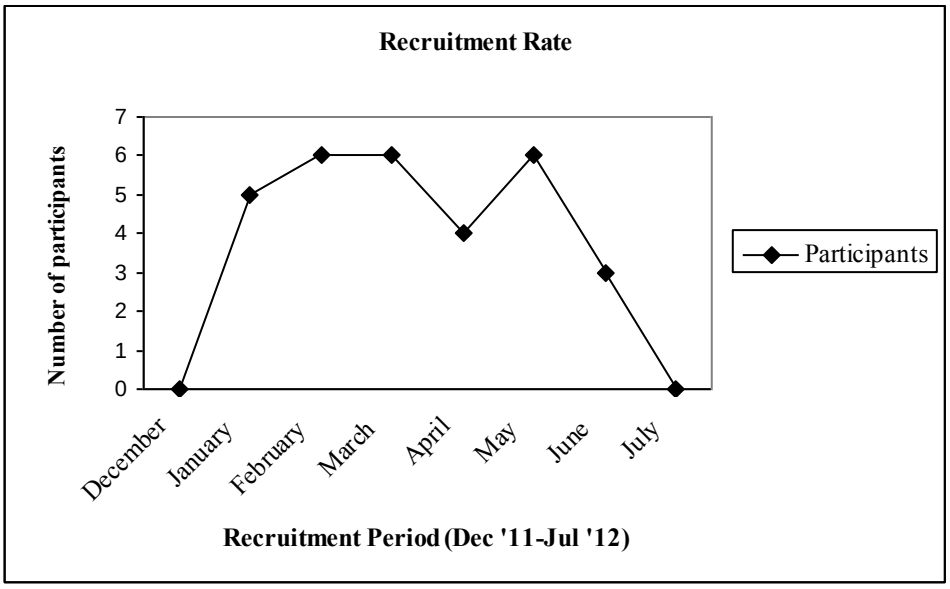

Figure 1. Number of participants recruited

Fifty-three participants were approached during MS clinics at Sheffield Teaching Hospitals (n=28) and at Nottingham University Hospitals (n=25). Of these, 17 (32%) agreed to participate. A total of 25 individuals were invited to take part via letters from consultant neurologists at Nottingham and 4 individuals agreed to take part (16%). Nine participants who agreed to take part were invited by various MS healthcare professionals. Due to practical reasons, it was difficult to confirm the number of participants who were directly invited by their clinicians and who were not interested in taking part. However, it is estimated that around 50 information packs were passed on to potential participants. If participants gave a reason for declining to take part this was recorded. Figure 2 describes a flow chart of recruitment.

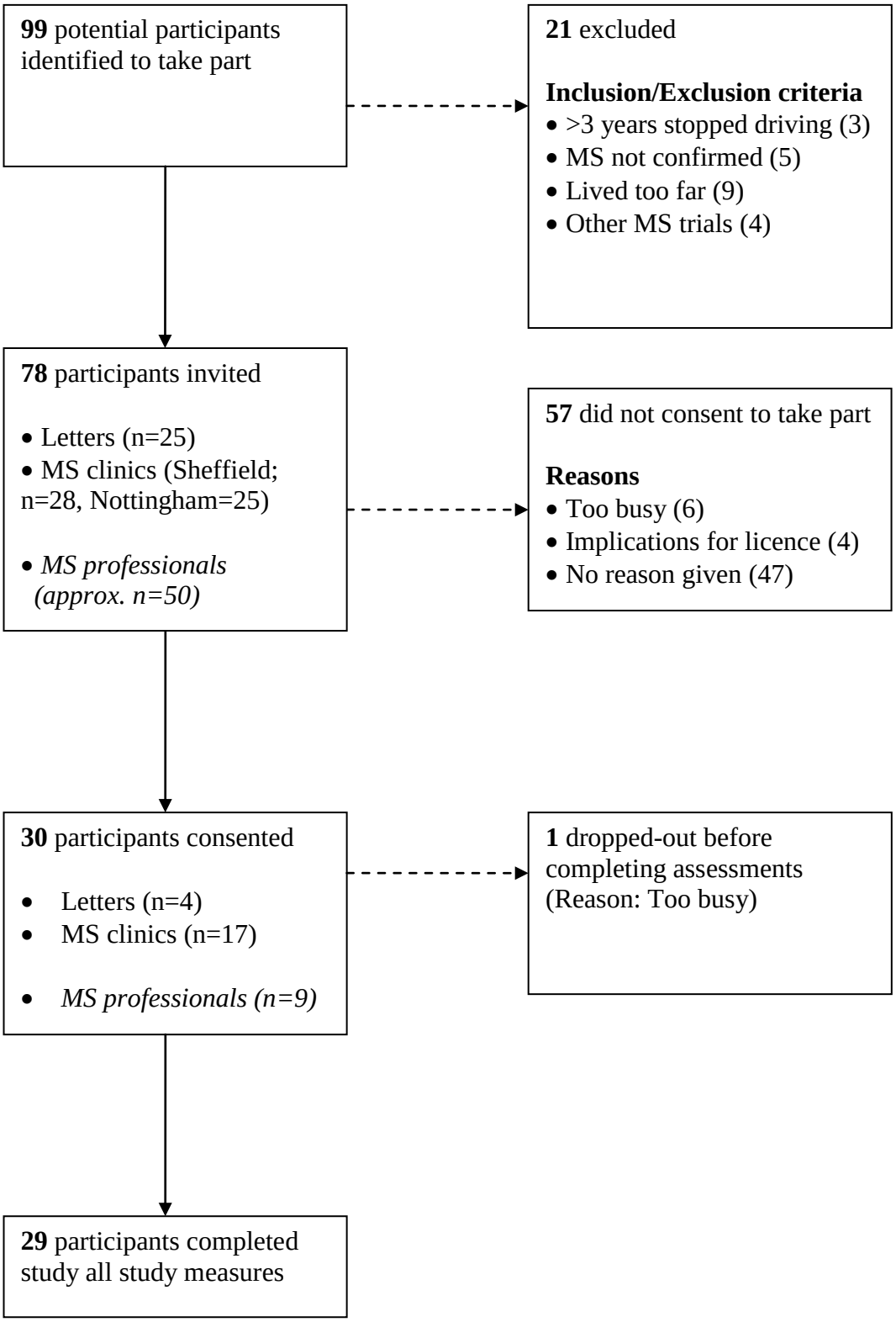

Figure 2. Flow chart recruitment diagram

Tables 1-3 show demographic, clinical and driving-related characteristics. Of the 29 participants who completed assessments 12 (41.4%) were male. The mean age of participants was 49.24 years (*SD*=8.37) ranging between 33 to 65 years.

Table 1

Description of Demographic Characteristics

	Mean (SD)	**Range**
Age	49.24 (8.37)	33-65
	Total n (%)	
Gender		
Male	12 (41.4)	
Female	17 (58.6)	
Education level		
<16yrs old	5 (17.2)	
GCSE/A levels	11 (37.9)	
Degree/Diploma	11 (37.9)	
Postgraduate	2 (6.9)	
Marital status		
Married	19 (65.5)	
Divorced/Separated	4 (13.8)	
Single	3 (10.3)	
Unknown	3 (10.3)	
Living arrangements		
With spouse/partner	13 (44.8)	
With others	11 (37.9)	
Alone	5 (17.2)	
Employment status		
Working	13 (44.8)	
Retired	6 (20.7)	
DLA/Unemployed	10 (34.5)	

Table 2

Description of Clinical Characteristics

	Mean (SD)	Range
MS duration (years)	9.05 (6.72)	.5-27
MS severity [a]	12.41 (5.68)	2-21
	Total n (%)	
MS type		
Relapsing-Remitting	16 (55.2)	
Primary Progressive	7 (24.1)	
Secondary Progressive	3 (10.3)	
Benign	2 (6.9)	
Unknown	1 (3.4)	
Other medical conditions		
Yes	11 (37.9)	
No	18 (62.1)	
MS medication		
Yes	18 (62.1)	
No	11 (37.9)	
Mood medication		
Yes	11 (37.9)	
No	18 (62.1)	

Note. [a] Guy's Neurological Disability Scale (max score=60, higher scores indicating greater disability).

Table 3 *Description of Driving Characteristics*

	Mean (SD)	Range
Driving experience (years)	29.28 (10.05)	6-47
	Total n (%)	
Driving status		
Yes	28 (96.4)	
No	1 (3.4)	
Current driving frequency		
Frequent	4 (13.8)	
Average	11 (37.9)	
Infrequent	13 (44.8)	
Driving frequency since MS		
More	3 (10.3)	
Same	12 (41.4)	
Less	13 (44.8)	
Occupation driving		
Yes	12 (41.4)	
No	17 (58.6)	
Advanced driving		
Yes	3 (10.3)	
No	26 (89.7)	
Driving accidents		
Yes	6 (20.7)	
No	23 (79.3)	
Traffic offences		
Yes	10 (34.5)	
No	19 (65.5)	

Ethical considerations

Service user involvement

Service user input was considered at the early stages of preparing the study protocol. Three service users were approached for advice regarding the aims, design, recruitment, practical issues, and ethical implications of this study. They argued that the current process of assessing fitness to drive is subjective and that any assessments that could inform the decisions of the clinical team before notifying the DVLA would be useful for the safety of the individual and the public. Recommendations were made to clarify confidentiality limitations and the process of assessing fitness to drive, which were addressed by making the required changes in the study design. It was suggested that individuals would be more likely to consider taking part if the study did not involve an on-road assessment and their test results would not be passed on to their clinicians.

Ethical approval

The study protocol was scientifically reviewed by two independent reviewers and a statistician from the University of Sheffield (Appendix A1). The study was granted ethical approval by Nottingham Ethics Committee in August 2011 (Appendix A2). It was approved by Research and Development departments of Sheffield Teaching Hospitals and Nottingham University Hospitals in November 2011 (Appendix A3).

Ethical approval was granted upon the condition that tests results would be fed back to participants' Consultant Neurologist and/or General Practitioner. Standard feedback letters were sent out to clinicians for participants who passed both neuropsychological assessments. For those participants with discrepant results this letter was complemented with a more detailed summary report and recommendations for an on-road assessment (Appendix B-Feedback letters).

Procedure

Information packs about the study included an Invitation Letter, a Reply Slip, an Information Sheet, and a Consent Form (Appendix C1-C3). Participants who were interested in taking part were asked to complete their contact details on the reply slip and return it using a pre-paid envelope provided. The contact details of the researcher were available, so that participants had the opportunity to discuss the study and ask questions. Figure 3 presents a summary of study procedure.

Participants who agreed to take part were required to sign a Consent Form when they met with the researcher. Assessments were administered at participants' place of residence. With regard to home visits, the relevant NHS Trust's lone working policy and university guidelines were followed. Although every effort was made to administer all assessments in a single 2-hour session, due to practical reasons some participants completed assessments in two sessions. Fatigue signs were monitored to ensure that participants were performing at their best. If required, participants were encouraged to take a short break between assessments as is recommended for neuropsychological testing in clinical settings.

The order of the two tests was counterbalanced, so that half participants were presented with MSDSA first (n=15) and the other half with the RDB first (n=14). Eight participants completed both assessments in one session and 21 participants in two sessions. The mean time between sessions was 6.34 days, range=2-24. There was no significant difference on MSDSA and RDB scores according to order of administration and number of sessions using Mann-Whitney U Tests ($p<.05$) (Appendix H-Table H1).

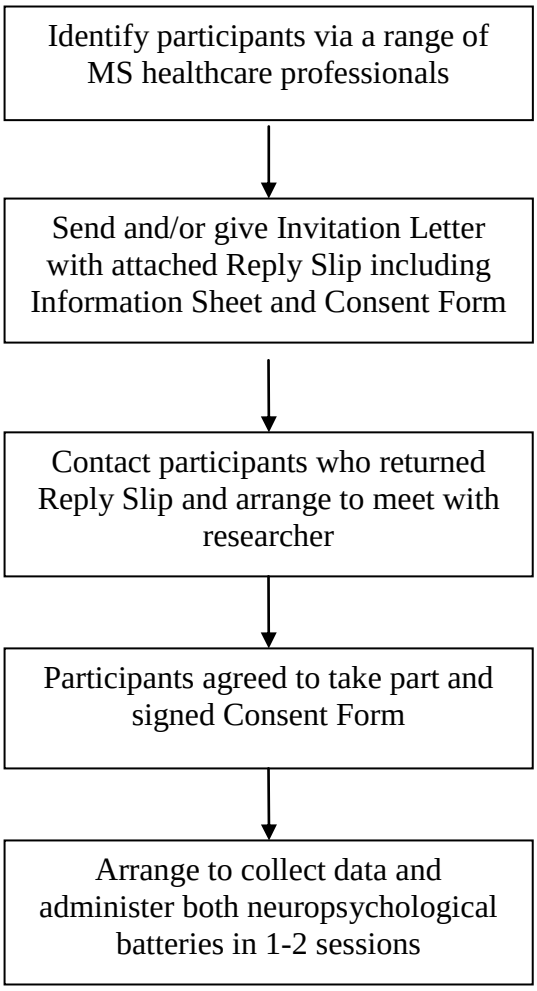

Figure 3. Summary of study procedure

Measures

Demographic and clinical data

A standard data collection form (Appendix D) was devised to record personal details, demographic and clinical characteristics. Information was also gathered about driving experience, recent accidents and driving offences, frequency of driving before and after the onset of MS, whether participants possess an advanced driving qualification and if their current or past occupation involves a lot of driving. The researcher asked participants to provide most of the information recorded on this form, so their medical records were not accessed to obtain any further information.

MS-Driver's Screening Assessment (MSDSA; Lincoln & Radford, 2008)

The MSDSA includes two subtests from the Stroke Driver's Screening Assessment (SDSA; Nouri & Lincoln, 1994) and two subtests from the Adult Memory and Information Processing Battery (AMIPB; Coughlan & Hollows, 1985). These subtests have been previously found predictive for identifying individuals with MS at risk of being unsafe on the road due to cognitive problems (Lincoln & Radford, 2008).

The SDSA Dot Cancellation and the Road Sign Recognition subtests have shown to assess attention, visuospatial and executive skills (Radford & Lincoln, 2004). The AMIPB is a 5-subtest battery of memory and information processing which has been found useful for assessing cognitive impairment in people with MS (Vlaar & Wade, 2003). The MSDSA takes approximately 20-30 minutes to complete and it includes the following subtests:

1) SDSA-*Dot Cancellation* requires participants to identify and cross out groups of four dots on an A4 sheet of three, four and five dots within 15 minutes. Completion time, omission errors and false positives are recorded.

2) SDSA-*Road Sign Recognition* assesses driving knowledge, visual comprehension and mental speed. It involves matching 19 road signs to 12 traffic situations in 3 minutes.

3) AMIPB-*Design Learning* assesses the ability to learn and consolidate new visual information. For this task participants learn a design and immediately reproduce it from memory by connecting dots over a maximum of 5 trials.

4) AMIPB-*Information Processing* is a timed subtest during which participants were required to perform a number of cancellation tasks.

MSDSA classifications were determined using the higher value on the predictive equation and the total score using the discrepancy between *pass* and *fail* equations (i.e., ≥0 safe; ≤0 =unsafe (Lincoln & Radford, 2008; Lincoln, Taylor, Vella, Bouman, & Radford, 2010). Classification equations derived from the original discriminant equation including the four MSDSA subtests (Appendix E-MSDSA Scoring Sheet). When the difference between *pass* and *fail* numerical values were ≤1 classifications were considered as *borderline.*

Rookwood Driving Battery (RDB; McKenna, 2009)

The RDB includes 12 subtests and it takes approximately 30-40 minutes to administer (Appendix F-RDB Scoring Sheet). It was developed for use as a screening tool in hospital and community settings to decide whether to refer an individual for an on-road assessment. It has been used as a further source of evidence to guide decision making about fitness to drive and to supplement the on-road assessment results (McKenna, 2009).

Based on models of neuropsychological functioning and driving behaviour (McKenna, 1998), the RDB assesses the following four cognitive domains: (a) *Visual Perception* reflecting the ability to interpret shapes, to be spatially aware and to efficiently monitor visual environment; (b) *Praxis Skills* assessing the ability to assess simple motor skills and to carry out rule dependent movements; (c) *Attention* including sustained or divided concentration on tasks; (d) *Executive Functioning* including problem-solving, self-monitoring and vigilance skills. *Language* is assessed as the ability to understand and follow verbal instructions, which is particularly relevant in an on-road assessment and in uncommon traffic situations. Subtests are presented by cognitive domain in Table 1. The 12 subtests are described by order of administration:

1) *Incomplete Letters* requires participants to identify 20 letters that are represented in fragmented black and white pictures.

2) *Position Discrimination* shows two squares with a dot inside each and participants are required to determine which dot is placed in the exact centre of the square.

3) *Cube Analysis* requires participants to count how many blocks appear in a three-dimensional drawing.

4) *Visual Es-Fs* is a simple letter cancellation task that requires marking target items within a large array of distracter letters.

5) *Key Search* requires participants to imagine that they lost their keys in a field and to draw a line in a square to show an effective search strategy for finding them.

6) *Copying-Gestures-Objects* requires copying a set of six simple hand movements demonstrated by the examiner, performing a gesture from a verbal description, and miming object use in response to verbal cues.

7) *Tapping-Sequencing* requires participants to follow tapping rule movements illustrated by the examiner and to learn a sequence of three hand movements by modelling the examiner.

8) *Sorting* requires the recognition of colour and shape as dimensions for grouping a set of 12 plastic coloured shapes.

9) *Comprehension* makes use of the stimuli of the Sorting subtest and participants are asked to move them according to instructions.

10) *Rule Shifts Cards* requires participants to change and follow a verbal rule while they are presented with a set of 20 standard black and red playing cards.

11) *Action Program* requires the development of an action plan in order to remove a cork from a tall tube while manipulating various pieces of apparatus and generating a complex sequence of actions.

12) *Divided Es-Fs* combines a retest of the previous letter cancelling task while also marking a box every time the word “three” is mentioned in an audio story.

Table 4 *Rookwood Driving Battery Subtests by Cognitive Domain*

	Profile Cut-off scores	Description and Origins
Visual Perception		
Incomplete Letters Position Discrimination Cube Analysis	19-20=0; 18=1; 0-17=2 fail≤ 18 19-20=0; 18=1; 0-17=2 fail≤ 18 10=0; 8-9=1; 0-7=2 fail ≤7	Three subtests to assess shape perception and visual spatial skills from the Visual and Spatial Recognition Perception battery (VOSP; Warrington & James, 1991)
Attention		
Visual Es-Fs Divided Es-Fs	fail ≤42 out of 86 targets fail ≤36 out of 86 targets, ≤ 5 "threes"	Two tasks of cognitive speed, visual and divided attention involving letter cancellation.
Praxis		
Copying-Gesture-Objects Tapping-Sequencing	16=0; 15=1; 0-14=2 fail≤14 14-15=0; 13=1; 0-12=2 fail≤2	Two subtests for copying hand movements, producing gestures, mining use of objects and following verbal and movement rules.
Executive Function		
Key Search Action Program Rule Shift Cards Sorting	10-16=0; 8-9=1; 0-7=2 fail≤5 5=0; 4=1; 0-3=2 fail ≤3 20=0; 18-19=1; 0-17=2 fail ≤17 4=0; 3=1; 0-2=2 fail≤3	Three subtests to assess non-verbal planning, problem-solving and ability to monitor a verbal rule from the Behavioural Assessment of the Dysexecutive Syndrome battery (BADS; Wilson et al., 1996). An adapted version of Weigl colour-form sorting test to assess abstract reasoning.
Comprehension	7-8=0; 6=1; 0-5=2 fail ≤6	Shortened version of the Modified Token Test (Coughlin & Warrington, 1978) to assess verbal and visual thinking.

Note. Raw scores converted to profile scores of 0 (good), 1 (borderline), 2 (poor). Fail criterion based on 5th percentile cut-off scores.

Raw scores on each subtest are converted to a profile of 0 (good), 1 (borderline) or 2 (poor) with the exception of the two visual and divided attention tests (Es-Fs) which convert to a score of 0 (good) or 1 (poor). The 5th percentile cut-off score is provided as the *fail* criterion for each subtest. An overall battery score is computed by adding all the subtest profile scores (min=0-max=22). Total battery scores greater than 10 are considered a *fail* and indicate that an individual is not safe to drive. Scores between 6 and 10 may also suggest a level of cognitive impairment which may influence driving ability. Lower scores (0-5) are considered a *pass* and indicate that that cognition is not compromised to an extent that an individual's driving ability is affected.

McKenna and Bell (2007) provided two clinical cut-off scores based on a larger standardisation study. A cut-off of ≥6 was recommended for individuals over 70 years old and a cut-off of >10 for younger individuals. Notably, 63% (n=342) of the standardisation sample included younger participants with diagnoses of stroke and traumatic brain injury, but very few individuals with MS (n=13, mean age=46). The predictive value of these two cut-off scores has not been adequately assessed in the MS population and the RDB manual clearly states that clinical judgement is required for scores between 6 and 10 when predicting driving ability. Therefore, this study used both cut-off scores to determine RDB *fail* scores in order to assess the level of agreement with MSDSA based on more and less stringent criteria.

Guy's Neurological Disability Scale (GNDS; Sharrack & Hughes, 1999a)

The GNDS was used to determine severity of physical disability. It is a comprehensive 12-item scale that assesses, by interview, the level of disability in the following areas: cognition, mood, vision, communication, swallowing, upper and lower function, bladder, bowel, sexual, fatigue, other. Range of scores is between 0-60 and each item is rated on a 0-5 scale with higher scores indicating greater difficulties (Appendix G-GNDS).

The GNDS is a self-report measure, which is brief and easy to be administered by any healthcare professional and it has been adequately validated for use in MS (Rossier & Wade, 2002). This measure was selected among other MS-specific disability measures as it assesses symptom severity on a wide range of functional systems. When reviewed by 33 international MS experts, 84% of them suggested that it has good face and content validity. It has been shown to have high internal consistency (.87), inter-rater reliability (.96) and validity when compared with other widely used physical disability scales (Sharrack & Hughes, 1999b).

Power calculation

An *a priori* power analysis was conducted based on Hypothesis 1, as the main aim of this study was to examine the agreement between two neuropsychological batteries for classifying people with MS either as safe or unsafe drivers. It is important to note that estimating effect sizes and the proportion of participants who may show discrepancies between the two cognitive assessments could have had a noticeable effect on the required sample size (Cantor, 1996; Flack, Afifi, Lachenbrunch, & Schouten, 1988). Power analysis for kappa agreement has several limitations as it tends to estimate the maximum standard of error which is unknown prior conducting a study (Cantor, 1996).

Cohen's Kappa test for agreement between two raters was computed using PASS 11 Power Analysis Software, which is based on Flack et al. (1988) paper for estimating the power and sample size for level of agreement between two tests. A sample size between 30-40 participants achieved 80% power to detect a true Kappa value of *very good* agreement (κ=0.80-0.90), when the estimated frequencies between raters were equal to 0.50 and 0.50 (p<.05). Null hypothesis would be rejected if kappa coefficients are below *very good* agreement for n<30.

The two neuropsychological batteries have been validated in small sample sizes (MSDSA, n=34; RDB, n=13), so the current study aimed at achieving a similar standard. Smaller sample sizes are common and justifiable in neuropsychological research due to the nature of cognitive testing and complexity of neurological populations (Bezeau & Graves, 2001).

Statistical analyses

Data were analysed using IBM SPSS Statistics version 19. Descriptive statistics were used to explore the distribution of cognitive test scores and to describe the characteristics of the sample. Test scores were converted from continuous to dichotomous *pass/fail* variables. Distributions of data were screened using histograms, normality plots and Kolmogorov-Smirnov tests.

Level of agreement between the two neuropsychological batteries was calculated using Cohen's kappa coefficient, which measures the proportion of agreement between two raters that each can classify N items into mutually exclusive qualitative categories. The frequency distribution of the RDB and MSDSA on *pass/fail* classifications was also assessed using contingency tables. Spearman's rho correlation analyses were conducted to determine the bivariate association between continuous variables. Differences on demographic, clinical and driving-related variables between participants' overall scores and *pass/fail* classifications were tested using Mann-Whitney U and Kruskal-Wallis tests. Chi-square χ^2 tests were used for categorical data. Regression analyses were used to examine which variables best predicted MSDSA and RDB outcomes. It is recommended to have 10-15 participants per predictor for reliable equations, so a maximum of three predictors was entered into each regression model (Stevens, 2002). The results of these analyses are to be interpreted cautiously due to data violating normality (Tabanick & Fidell, 2007). Other assumptions (linearity, homoscedasticity, and residuals) determining the robustness of regression analyses were sufficiently met.

Results

Data screening

Data were screened using both visual and statistical methods to assess normality and to determine suitability for parametric versus non-parametric statistics. The distribution of overall and subtest cognitive scores was investigated by skewness and kurtosis values. Histograms and normality Q-Q plots revealed that most scores were not normally distributed. The z skewness formula[2] was calculated and values were greater than the recommended absolute value of 1.96 at $p<.05$, which suggested that data significantly differ from the normal distribution (Field, 2009). Kolmogorov-Smirnov (K-S) normality tests were performed for RDB and MSDSA subtests and most of them were significantly different from the normal distribution ($p<.05$). The z skewness values and K-S normality statistics are shown in Table 5. Outliers were identified using box-plots and when extreme scores were removed this made no difference to the skewness of distribution. Data transformation was not considered appropriate for improving normality. Altering the relative distances between data points raises issues for data interpretation due to the curvilinear nature of transformations (Osborne, 2002). Therefore, non-parametric statistics were used for further statistical analyses.

[2] z skewness formula= (skewness-0) / standard error of skewness.

Table 5

Normality Data for Cognitive Measures

	z skewness [a]	K-S [b] p-value
MSDSA		
Dot Cancellation		
-Time	1.47	.19
-Errors	2.84	**.01****
-False positives	4.15	**.00***
Road Sign Recognition	-1.74	**.00***
Design Learning	-1.72	.20
Information Processing-Adjusted	-0.84	.20
MSDSA Total	-0.03	.20
RDB	**-2.89**	
Incomplete Letters		**.00***
Position Discrimination	**-4.08**	**.00***
Cube Analysis	**-3.12**	**.00***
Es-Fs Visual	**-2.53**	**.00***
Key Search	0.04	**.01****
Copying-Gesture-Objects	**-10.60**	**.00***
Tapping-Sequencing	**-6.13**	**.00***
Sorting	**-7.14**	**.00***
Comprehension	**-2.65**	**.00***
Cards	**-5.09**	**.00***
Action Program	-1.59	**.00***
Es-Fs Divided	**-4.03**	**.00***
RBD Total	1.94	**.04****

Note. [a] Absolute values above 1.96 at $p<.05$ and above 2.58 at $p<.01$ are non-normal. [b] Kolmogorov-Smirnov Lilliefors Correction Significance. *$p<.001$, ** $p<.05$ (two-tailed).

Descriptive statistics

The total sample size was 29 for all study measures and statistical analyses computed. Median (*Mdn*) and interquartile range (*IQR*) values were reported for representing distribution of scores as most variables were not normally distributed. Severity of physical disability as measured by the GNDS ranged between 2 and 21 (*Mdn*=14), with higher total and item scores indicating greater disability. Individual items measuring fatigue, lower limb, and bladder function had the highest median scores of 2 suggesting mild disability. The mean of the cognition item was 1.34 (*SD*=.97, range=0-3). GNDS total and item scores are presented in Table 6.

Table 6

Descriptive Statistics for Guy's Neurological Disability Scale (n=29)

	Range Potential	Range Actual	Mean	SD	Median	IQR
GNDS Total [a]	0-60	2-21	12.41	5.68	14	7-10
Cognition	0-5	0-3	1.34	.97	1	0-2
Mood	0-5	0-3	1.21	1.05	1	0-2
Vision	0-5	0-2	.31	.60	0	0-1
Communication	0-5	0-2	.41	.73	0	0-1
Swallowing	0-5	0-1	.21	.41	0	0
Upper-limb	0-5	0-4	1.14	1.16	0	0-2
Lower-limb	0-5	0-4	1.52	1.15	2	0-2
Bladder	0-5	0-4	1.52	1.43	2	0-2
Bowel	0-5	0-2	.41	.73	0	0-1
Sexual	0-5	0-4	.41	1.15	0	0
Fatigue	0-5	0-5	2.31	1.23	2	2-3
Other	0-5	0-4	1.69	1.29	2	0-3

Note. *SD*=Standard Deviation; *IQR*=Interquartile Range
[a] Higher GNDS total and item scores indicate greater disability.

Table 7 shows descriptive statistics for the MSDSA scores. Higher subtest scores, except for Dot Cancellation, indicate better outcomes. Most participants scored within the average range on all MSDSA subtests. The median MSDSA total scores (*Mdn*=2, *IQR*=0-3) suggested that the majority of participants performed well overall and received a *pass* classification.

Table 7

Descriptive Statistics for MS-Driver's Screening Assessment (n=29)

	Range Potential	Range Actual	Mean	SD	Median	IQR
Dot Cancellation						
-Time	900 (max)	230-710	434.00	119.76	421	353-488
-Errors	_	0-37	10.45	9.79	8	3-16
-False positives	_	0-3	.48	.95	0	0-1
Road Sign Recognition	0-12	4-12	9.31	2.47	9	8-11
Design Learning						
-Total	0-45	5-44	31.83	9.37	33	25-41
-Recall	0-9	0-9	6.17	2.70	7	4-9
-Interference	0-9	0-9	4.14	.41	4	2-5
-Errors	_	0-28	10.59	7.60	9	4-16
Information Processing						
-Total	0-105	26-83	56.48	17.15	57	48-69
-Speed	0-90	20-80	50.66	14.83	53	44-53
-Errors	0-105	0-3	.24	.69	0	0-0
-Adjusted	4-115	28-92	62.24	19.36	62	53-77
MSDSA Total [a]	_	-3 to 7	2.10	2.26	2	0-3

Note. *SD*=Standard Deviation; *IQR*=Interquartile Range
[a] MSDSA total was the discrepancy score between *Pass* and *Fail* equations (scores ≤0 indicate worse performance).

There was a ceiling effect for most RDB subtest scores as their mean scores approached the maximum possible score and the standard deviations were generally small (see Table 8). RDB total scores range between 0 and 8 suggesting that participants had mild cognitive difficulties. The median RDB total score was 3, indicating that participants overall level of cognitive impairment may not affect driving abilities.

Table 8

Descriptive Statistics for Rookwood Driving Battery (n=29)

	Range Potential	Range Actual	Mean	SD	Median	IQR
Incomplete Letters	0-20	17-20	19.38	.82	20	19-20
Position Discrimination	0-20	16-20	19.34	.97	20	19-20
Cube Analysis	0-10	8-10	9.66	.55	10	9-10
Es-Fs Visual						
-targets reached	0-86	40-86	74.41	14.41	82	66-86
-targets missed	0-86	0-6	.76	.76	0	0-1
-errors %	-	0-13	1.29	1.29	0	0-2
Key Search	0-16	7-16	12.00	2.30	12	11-14
Copying-Gesture-Objects	0-16	11-16	15.72	.96	16	16-16
Tapping-Sequencing	0-15	10-15	14.38	1.09	15	14-15
Sorting	0-4	2-4	.83	.54	4	3-4
Comprehension	0-8	4-8	7.00	1.00	7	6-8
Cards	0-20	16-20	19.45	1.06	20	19-20
Action Program	0-5	4-5	4.66	.48	5	4-5
Es-Fs Divided						
-targets reached	0-86	0-86	69.83	20.92	78	62-86
-targets missed	0-86	0-5	1.10	1.46	1	0-2
-errors %	-	0-7	1.75	1.87	1	0-3
-auditory targets	0-9	7-10*	8.76	.58	9	8-9
RDB Total [a]	0-22	0-8	2.52	1.94	3	1-4

Note. *One participant identified an additional target and scored outside the range.
[a] Higher RDB total scores indicate worse performance.

RDB subtest scores were converted to profile scores (pass, borderline, fail) for computing the overall battery score. These are shown in Table 9. The majority of participants received *pass* profile scores. Nine participants (31%) received *borderline* scores on the Cube Analysis and 10 participants (34.5%) on the Action Program subtests, however none scored below the *fail* cut-off on these tasks. Although very few participants scored below the 5th percentile cut-off score on individual subtests, the most frequently failed subtests were the Es-Fs (attention), Cards, Sorting, and Comprehension (executive skills).

Table 9

Frequencies for RDB Subtest Profile Scores

	Pass n (%)	**Borderline n (%)**	**Fail n (%)**
Incomplete Letters	25 (86.2)	3 (10.3)	1 (3.4)
Position Discrimination	24 (82.8)	4 (13.8)	1 (3.4)
Cube Analysis	20 (69.0)	9 (31.0)	0
Es-Fs Visual	27 (93.1)	_	2 (6.9)
Key Search	26 (89.7)	2 (6.9)	1 (3.4)
Copying-Gesture-Objects	25 (86.2)	3 (10.3)	1 (3.4)
Tapping-Sequencing	25 (86.2)	3 (10.3)	1 (3.4)
Sorting	26 (89.7)	1 (3.4)	2 (6.9)
Comprehension	22 (75.9)	5 (17.2)	2 (6.9)
Cards	20 (69.0)	6 (20.7)	3 (10.3)
Action Program	19 (65.5)	10 (34.5)	0
Es-Fs Divided	28 (96.6)	_	1 (3.4)

Note. Es-Fs converted to *Pass* and *Fail* profile scores

Hypothesis 1: Very good agreement between RDB and MSDSA classifications

The association between RDB and MSDSA classifications was assessed using 3x3 (Pass/Borderline/Fail) and 2x2 (Pass/Fail) contingency tables with observed and expected frequencies. Tables 10 and 11 describe RDB and MSDSA classifications using >10 and ≥ 6 cut-off criteria (see Method). Two participants (6.8%) with RDB total scores between 6 and 10 were classified as *borderline* and there were no *fail* classifications using the less stringent cut-off criterion (>10). Six participants (20.6%) were *borderline* when the discrepancy between *pass* and *fail* MSDSA equations was a numerical value ≤1. For 21 participants (72.4%) there was agreement between MSDSA and RDB *pass* classifications.

Table 10

Comparison between RDB and MSDSA Classifications (Pass/Borderline/Fail)

	Rookwood Driving Battery [b]			
MS-Driver's Screening Assessment [a]	Pass n (%)	Borderline n (%)	Fail n (%)	Total N (%)
Pass	21 (72.4)	0	0	21 (72.4)
Borderline	5 (17.2)	1 (3.4)	0	6 (20.6)
Fail	1 (3.4)	1 (3.4)	0	2 (6.8)
Total	27 (93.1)	2 (6.8)	0	29 (100)

Note. MSDSA and RDB classified into *Pass*, *Borderline*, *Fail* groups
[a] Pass/Fail=Higher value on predictive equation, Borderline=discrepancy of ≤1 between Pass/Fail equations. [b] Pass=0-5, Borderline Fail=6-10, Fail=11-22.

When RDB *borderline* cases were classified as *fail* using the more stringent cut-off criterion (≥6), the percentage of agreement between MSDSA and RDB *pass* classifications was increased (82.8%). For 2 participants (6.9%) there was not a discrepancy between *fail* classifications. The MSDSA had 100% (2/2) sensitivity for *fail* and 88.9% (24/27) specificity for *pass* compared to the RDB, which is the screening test used in current clinical practice.

Table 11

Comparison between RDB and MSDSA Classifications (Pass/Fail)

		Rookwood Driving Battery [b]	
MS-Driver's Screening Assessment [a]		**Pass**	**Fail**
	Count	**24**	**0**
Pass	Expected	22.3	1.7
	% within MSDSA	100.0	0
	% within RDB	88.9	0
	% Total	82.8	0
	Count	**3**	**2**
Fail	Expected	4.7	0.3
	% within MSDSA	60.0	40.0
	% within RDB	11.1	100.0
	% Total	10.3	6.9

Note. 3 cells have expected count less< 5. [a] Higher score on the predictive equation score indicates Pass/Fail outcomes. [b] Fail outcome based on cut-off score ≥6.

The expected cell count on the 2x2 contingency table was less than 5 and this violated assumptions for a Chi-Square test. Therefore, the Fisher's Exact Probability test was computed to explore the association between MSDSA and RDB classifications. This indicated a significant association (p=.03) with a large effect size (phi φ=.60, p<.001) based on Cohen's (1992) criteria (small=.10, medium=.30, large=.50).

Cohen's Kappa was calculated to assess inter-rater agreement between MSDSA and RDB classifications. It measures agreement rather than association and is less sensitive to chance findings (Feingold, 1992). Kappa value was 0.53 with a significance of p<.001, which suggested a *moderate* level of agreement between MSDSA and RDB classifications (>0.50=moderate, >0.70=good, >0.80=very good).

Hypothesis 2: Individual subtests will be predictive of MSDSA and RDB performance

Spearman's correlations were calculated between MSDSA total and subtest scores. These are presented in Table 12. The MSDSA total score was significantly correlated with the Road Sign Recognition (p<.001) and Information Processing scores (p<.01).

Table 12

Correlations between MSDSA Subtests

		DC-T	DC-E	FC-F	RSR	DL	IP-A
MSDSA Total	**r**	.22	-.29	-.14	**.67*****	-.01	**.46****
Dot Cancellation Time **(DC-T)**		_	-.13	.20	-.21	**-.47****	**-.47****
Dot Cancellation Errors **(DC-E)**			_	-.12	-.13	-.30	**-.51****
Dot Cancellation False Positives **(DC-F)**				_	-.22	-.13	-.10
Road Sign Recognition **(RSR)**					_	**.44***	**.52*****
Design Learning **(DL)**						_	**.61*****
Information Processing-Adjusted **(IP-A)**							_

*p<.05, **p<.01, ***p<.001 (two-tailed).

Correlations were computed for RDB total score and its subtests, which are summarised in Table 13. The Incomplete Letters, Key Search, Copying-Gestures-Objects, Tapping-Sequencing, and Sorting subtests were not significantly correlated with the RDB total scores or any other subtests (Appendix H-Table H2). All remaining subtests with lower scores (indicating greater cognitive difficulties) were significantly associated with a higher total score (indicating greater impact on driving ability). Strength of correlations was large (r_s=-.53 to -.72) for Position Discrimination, Comprehension, Visual and Divided Es-Fs subtests, suggesting a strong relationship between these subtests and the RDB total score.

The relationship between MSDSA and RDB subtests was also investigated and the results are presented in Table 14. MSDSA and RDB total scores were moderately associated (r_s=.37, p<.05). MSDSA total scores were not significantly correlated with any of the RDB subtests, but RDB total score was significantly associated with all except one MSDSA subtest (Dot Cancellation-false positives). Attention as measured by the Dot Cancellation completion time was significantly associated with the Es-Fs Visual and Divided attention RDB subtest. The two executive functioning tasks related to driving skills, the MSDSA Road Sign Recognition (driving knowledge) and the RDB Key Search (route planning) were significantly correlated (r_s=.38, p<.05). RDB Incomplete Letters, Cube Analysis, Tapping-Sequencing, Cards, and Action Program subtests were not significantly correlated with MSDSA total and subtest scores (Appendix H-Table H3).

Table 13

Correlations between RDB Subtests

		PD	CA	V	KS	C	RSF	AP	D
RDB Total	**R**	**-.55****	**-.19*****	**-.72*****	.04	**-.53****	**-.43***	**-.49****	**-.54****
Position Discrimination **(PD)**		_	-.12	**.45***	.22	.27	.19	**.53****	.24
Cube Analysis **(CA)**			_	-.01	**-.43***	.12	-.30	-.03	-.04
Es-Fs Visual **(V)**				_	-.08	.28	.21	**.41***	**.74*****
Key Search **(KS)**					_	-.13	.13	.23	-.26
Comprehension **(C)**						_	.22	-.01	.19
Rule Shift Cards **(RSF)**							_	-.02	.01
Action Program **(AP)**								_	.25
Es-Fs Divided **(D)**									_

Note. Incomplete Letters, Copying-Gestures-Objects, Tapping-Sequencing, Sorting subtests not included as they were not significantly correlated with total and subtest scores.
**p*<.05, ***p*<.01, ****p*<.001 (two-tailed).

Table 14

Correlations between RDB and MSDSA Subtests

		MSDSA Total	DC Time	DC Errors	RSR	DL	IP-A
RDB Total	**r**	**.37***	**.45***	**.39***	**-.54****	**-.44***	**-.70*****
Position Discrimination		.33	**-.47****	-.13	**.45***	.11	**.44***
Es-Fs Visual		.23	**-.69*****	-.27	**.43***	**.46****	**.76*****
Key Search		.24	.12	.19	**.38***	-.14	-.15
Coping-Gestures-Objects		-.24	-.23	**.43***	-.22	-.06	-.10
Sorting		.35	.06	**-.48****	.27	.07	.35
Comprehension		.07	.23	-.28	.17	**.39***	**.38***
Es-Fs Divided		.22	**-.59*****	-.23	.27	**.46****	**.77*****

Note. DC False positives, Incomplete Letters, Cube Analysis, Tapping-Sequencing, Cards, Action Program not included as not significantly correlated with any total and subtest scores.
*p<.05, **p<.01, ***p<.001 (two-tailed).

Table 15

Comparison of Pass and Fail classifications on the MSDSA

	Pass n=24		Fail n=5		Mann-Whitney U	p-value
	Median	**IQR**	**Median**	**IQR**		
Dot Cancellation						
-time	426.50	362-491	352	295-528	42	.32
-errors	7.50	3-13	21	3-33	37.50	.20
-false positives	0	0-0	0	0-0	42.50	.30
Road Sign	8	9-12	7	4-8	12	**.01***
Design Learning	32.50	32-39	40	24-43	44	.37
Information Processing-Adjusted	64.50	55-77	54	31-76	43	.34

*p<.01, (two-tailed).

Table 15 shows the differences between the MSDSA *pass* and *fail* groups for each of its subtests. The exact significance value (p<.05, two-tailed) was used as it is recommended for smaller sample sizes (Field, 2009). Scores for the Road Sign Recognition subtest differed between *pass* and *fail* classifications. None of the other subtests showed any significant difference between the two groups.

Table 16

Comparison of Pass and Fail Classifications on the RDB

	Pass n=27		Fail n=2		Mann-Whitney U	p-value
	Median	**IQR**	**Median**	**IQR**		
Incomplete Letters	20	19-20	19	19-19	15	.49
Position Discrimination	20	19-20	17	16-17	1.5	**.01****
Cube Analysis	10	9-10	9.50	9-10	22	1.00
Es-Fs Visual	82	70-86	52.50	46-52	4.5	**.03***
Key Search	12	12-14	11	11-11	19	.58
Copying	16	16-16	16	16-16	23	1.00
Tapping-Sequencing	15	14-15	12	10-12	6	**.03***
Sorting	4	4-4	3	2-3	15	.14
Comprehension	7	7-8	7	6-7	26.5	1.00
Cards	20	20-20	18.50	17-18	19	.70
Action Program	5	5-5	4	4-4	8	.11
Es-Fs Divided	80	64-86	49.50	38-49	7	.12

*p<.05, **p<.01 (two-tailed).

Table 16 presents the differences between the *pass* and *fail* groups of the RDB and each of its subtests. Using Mann-Whitney tests, a significant difference was found between the two groups for Position Discrimination and Tapping-Sequencing subtest scores. Significant difference between the two groups was also found for the number of targets reached on the Es-Fs visual subtest (p=.03). Participants who failed RDB had significantly worse scores on these three subtests compared to those who passed. Other subtests showed no significant differences between participants who passed or failed the overall battery.

Subtests predicting MSDSA and RDB outcomes

Regression models were used to evaluate how well MSDSA subtests could predict its overall outcome. Road Sign Recognition and Information Processing were significantly related with MSDSA total scores, but only the former with *pass/fail* classifications. These two subtests were entered into logistic and linear regression models as independent variables using the Enter method. The results of these models are shown in Table 17.

Logistic regression was carried out to test a model predicting MSDSA *pass/fail* classifications. Road Sign Recognition was the only predictor significantly contributing to the model ($p<.05$) with 82.8% accuracy, 91.7% sensitivity for *pass*, and 40% specificity for *fail* (see Table 18).

Table 17

Regression Models Predicting MSDSA Outcome

Logistic	**B (OR)**	**SE**	**R^2**	**Wald χ^2**	**p-value**
Road Sign	-.70 (.49)	.29	.26-.43	5.53	**.02***
Information Processing	.01 (1.01)	.03		.14	.70
Linear	**B (95% CI)**	**SE**	**Adjusted R^2**	**t**	**p-value**
Road Sign	.54 (.17, .82)	.16	.38	3.11	**.01***
Information Processing	.19 (-.02, .06)	.02		1.08	.29

Note. B=Beta Standardised Coefficients; CI=Confidence Interval; SE=Standard Error; OR=Odds Ratio. *$p<.01$, two-tailed.

Linear regression model with MSDSA total scores as the dependent variable was significant ($F_{2,26}$=9.67, p<.001), but only including Road Sign Recognition as a significant predictor (p=.005). The Adjusted R^2 indicated that this model accounted for 38% of the variance in MSDSA total scores.

Table 18

Observed and Predicted Frequencies for MSDSA Classifications by Logistic Regression

	Predicted		
Observed	**Pass**	**Fail**	**% Correct**
Pass	22	2	(24) 91.7% [a]
Fail	3	2	(5) 40.0% [b]
	25 (88%) [c]	4 (50%) [d]	(29) 82.8%

Note. [a] Sensitivity (22/24). [b] Specificity (2/5). [c] Positive Predictive Value (22/25) [d] Negative Predictive Value (2/4)

Similarly, a regression model was used to evaluate the predictive value of RDB subtests with its total scores. The critical level of significance used for including independent variables in the regression models was p<.001 which is recommended for smaller sample sizes and for avoiding Type I errors (Field, 2009). Subtests significantly related to RDB total scores and subtests frequently failed were considered. A maximum number of three subtests could be added to meet sample size assumptions. Subtests assessing similar cognitive abilities were not included to avoid singularity which can occur when predictor variables are highly correlated (e.g., Es-Fs Visual versus Position Discrimination). Linear regression was performed using the Enter method including the Es-Fs Visual and Comprehension subtests as predictor variables.

Linear regression model with RDB total scores as the dependent variable was significant ($F_{2,26}$=20.06, p<.001) including both the Es-Fs Visual (attention and perception) and Comprehension (verbal reasoning) subtests as significant predictors. The standardized Beta regression coefficients show that Es-Fs Visual (-.61) was a stronger predictor than Comprehension (-.40). The Adjusted R^2 indicated that this model accounted for 58% of the variance in RDB total scores. Linear regression model for RDB is presented in Table 19. Logistic regression was not performed for RDB classifications because they were limited cases in the *fail* category (<5) of the dependent variable, which may result in computational problems (Pallant, 2007; Tabanick & Fidell, 2007).

Table 19

Regression Model Predicting RDB outcome

Linear	**B (95% CI)**	**SE**	**t**	**Adjusted R^2**	**p-value**
Es-Fs Visual	-.61 (-.12, -.05)	.02	-4.875	.58	**.00***
Comprehension	-.40 (-1.28, -.29)	.24	-3.347		**.00***

Note. B=Beta Standardised Coefficients; CI=Confidence Interval; SE=Standard Error; OR=Odds Ratio. *p<.001, two-tailed.

Hypothesis 3: Clinical characteristics will not be associated with RDB and MSDSA

The association between sample characteristics and classification on either of the two neuropsychological batteries was investigated. Bonferroni corrections[3] were used to adjust any significant findings again the number of comparisons (independent variables with 2 groups, $p<.03$; 3 groups, $p<.02$; 4 groups, $p<.01$). However, non-significant results were reported using a less restrictive significance level ($p<.05$).

No significant differences in age, time since MS onset and years of driving experience were found between those who passed and those who failed the MSDSA using Mann-Whitney U tests. Physical disability, as measured by the GNDS, did not discriminate those participants who passed or failed the MSDSA. Chi-square χ^2 tests were computed for categorical variables with two or more categories. Expected frequencies of fewer than five violated chi-square assumptions, so the Fisher's Exact test was used instead. There were no significant associations either between MSDSA *pass/fail* classifications and any of the demographic, clinical or driving-related characteristics. The only significant finding was between MSDSA classifications and occupational driving ($F_{exact}=.007$, $p<.01$), with all participants who failed (n=5) reporting that their occupation involved a lot of driving. No other significant findings were found between sample characteristics and RDB classifications. These results are shown in Tables H4-H5 (Appendix H).

Table 20 summarises correlations between continuous variables and total scores on both batteries. Age, MS duration, and driving experience were not significantly correlated with MSDSA and RDB scores. Physical disability was significantly related to RDB ($r_s=.55$, $p<.01$), but not to MSDSA scores. Participants who scored higher on the RDB (indicating greater cognitive impairment) scored significantly higher on the GNDS (indicating greater disability).

[3] Bonferroni correction=level of significance/number of comparison groups.

Table 20

Correlations between Continuous Variables and Scores on the RDB and MSDSA

	MSDSA	RDB
Age	.22	.31
Physical disability	.09	**.01***
MS duration	.15	.21
Driving experience	.19	.11

*p<.01

Mann-Whitney U tests were computed to explore the association between sample characteristics with two categories (i.e., Yes/No, Male/Female) and MSDSA scores. Participants who self-reported traffic offences (*Mdn*=3.8) in the past five years had better total scores than those who did not (*Mdn*=1.8) (*U*=41, p<.01). Occupational driving revealed significantly better MSDSA scores between participants who were driving as part of their job (*Mdn*=.64-Yes group) than those who did not (*Mdn*=2.6-No group) (*U*=38, p<.001). No significant differences were found between MSDSA scores and any other sample characteristics. Also, there were no significant differences between RDB total scores and any categorical sample characteristics (p<.05).

Kruskal-Wallis tests were performed for categorical independent variables with three or more categories and the total scores of both batteries. No significant differences were found in MSDSA scores across demographic variables such as living arrangements, educational level, marital status or clinical variables such as MS subtype. Non-significant findings were also reported between RDB scores and these variables. However, a statistically significant difference was found in RDB scores across different working status (*H*=3.96, p<.05) and driving frequency (*H*=4.80, p<.05) groups. Retired participants and those driving less since the onset of their MS recorded higher median scores (worse performance) than the other groups. Based on Bonferroni adjustment for group comparisons (3 groups, p<.02) these significant results should be cautiously interpreted. These results are summarised in Appendix H-Table H6.

Discussion

The aim of this study was to evaluate how well the MSDSA, a screening battery specifically developed for people with MS, was associated with the RDB, a generic battery for all neuropsychological conditions. Both batteries have been validated against an on-road test, which is considered the clinical standard for assessing fitness to drive (Lincoln & Radford, 2008; McKenna & Bell, 2007). Therefore, it was attempted to determine the concurrent validity of the MSDSA compared to the RDB, which is the screening test widely used in clinical practice. The predictive validity of individual subtests from each battery was investigated in order to identify those that are most clinically useful in the MS population. The relationship between sample characteristics and the outcomes of both batteries was also explored.

The study identified a high proportion of safe drivers and 26 participants (90%) were consistently classified by both assessments (24 *passes*; 2 *fails*). Results showed that there was *moderate* agreement (κ=0.53, p<.001) between the MSDSA and RDB in this group of MS individuals with mild physical and cognitive deterioration. Only the MSDSA Road Sign Recognition (mental speed, visual memory, executive functioning) differentiated between MSDSA *pass*/*fail* classifications. The Road Sign Recognition accounted for 38% of the variance in MSDSA total scores and it was a significant predictor of MSDSA classifications (sensitivity for pass 92%, specificity 40%). The RDB Visual Es-Fs (visual attention, perception) and Comprehension (verbal executive skills) subtests yielded a model that accounted for almost 60% of the variance in RDB total scores.

MSDSA and RDB classifications

Classifications for each battery were assigned according to recommendations for clinical work. Any *borderline* scores on the RDB indicate possible difficulties with driving, so these were assigned to the same group as *fail* scores (McKenna, 2009). The MSDSA borderline passes and passes were assigned to a *pass* group and borderline fails and fails to a *fail* group. Lundberg, Caneman, Samuelsson, Hakamies-Blomqvist, and Almkvist (2003) supported a similar approach when using predictive equations to prevent *fail* classifications in individuals who ultimately may be safe to drive.

Studies on fitness to drive in neurological conditions have variably defined and used *sensitivity* and *specificity,* which can be problematic. For instance, McKenna and Bell (2007) acknowledged that these terms were incorrectly applied in one validation study of the RDB. This study applied sensitivity and specificity in relation to either *pass* or *fail* classifications. Results were more clinically relevant regarding the ability of a test to better identify *fail* rather than *pass* classifications.

Agreement between MSDSA and RDB

The majority of participants in this study were found to be safe drivers with a high percentage of agreement between MSDSA and RDB for *pass* classifications (83%). Most participants reported cognitive difficulties that affected their everyday functioning and this fits with research suggesting that such difficulties have a negative impact on daily activities of people with MS (Goverover, Genova, Hillary, & DeLuca, 2007). However, very few participants presented with significant cognitive deficits or these did not appear sufficient to compromise their driving ability. Participants who failed either one or both of the batteries explained that they were unaware that cognitive difficulties may influence their driving performance. One participant who received a *borderline pass* on the MSDSA and a *pass* on the RDB had decided to stop driving because of physical limitations. Two participants with *fail* classifications on both batteries reported

increasingly becoming more aware of their diminished driving skills as they were adapting or restricting their driving behaviours (e.g., driving less, shorter distances, avoiding night driving). Lincoln (1981) found that individuals with MS cannot realistically rate their own ability in daily activities, which could also suggest reduced insight into driving skills. In contrast, previous studies in MS and Parkinson's disease found that participants who were not aware of or who misjudged their cognitive deficits were less likely to engage in compensatory driving behaviours (Devos et al., 2007; Ryan et al., 2009).

The MSDSA had 100% sensitivity for *fail* (2/2), defined as the number of participants who received *fail* classifications compared to the RDB. The MSDSA detected more participants as unsafe to drive (n=5) compared to the RDB (n=2). The most likely explanation for this discrepancy might be that the RDB is a generic battery, so it could be less sensitive in identifying unsafe individuals with MS. This finding is in line with the BPS (2001) 'Fitness to Drive' recommendations that the same cognitive measures are unlikely to be appropriate for all neurological conditions. Furthermore, there is limited evidence regarding RDB cut-off scores for individuals with MS. The predictive value of the RDB between younger versus older adults has been investigated, but not between neurological conditions with different patterns of cognitive deterioration (McKenna & Bell, 2007; Rees et al., 2008). The RDB detected no participants as unsafe to drive using the more stringent cut-off score >10 and only two participants as unsafe using the less stringent cut-off score ≥6. On the RDB, most participants obtained maximum scores in certain subtests indicating that it may not be sensitive enough to detect mild cognitive deficits. This also suggests that some cognitive deficits, which may be characteristic of MS, were not tested by the RDB.

In relation to the previous point, there was a moderate association between MSDSA and RDB total scores indicating that they share measurement of some cognitive abilities. Individual subtests from each battery have been shown to predominantly assess attention, perception and executive skills (Radford & Lincoln, 2004; McKenna et al., 2004). However, a difference between the two batteries appears to be that the RBD places emphasis on praxis, executive and verbal skills, whereas the MSDSA emphasises visuoperceptual and non-verbal skills.

The MSDSA total score was not significantly related with any of the RDB subtests. A possible explanation for the lack of association could be how the MSDSA total score was calculated. In similar studies by Lincoln et al. (2006, 2010) the discrepancy score between *pass* and *fail* equations was used. Other studies have developed and used clinically applicable discriminant equations for predicting *pass/fail* classifications, but the issue of how to best determine total scores has not been adequately addressed. Akinwuntan et al. (2012b) suggested that further investigations are needed in cases when there is a small numerical difference (≤2) between *pass/fail* equations.

Predictive validity of individual subtests

Research to date supports that a combination of cognitive tests are better predictors of on-road outcomes than individual test scores (BPS, 2001). However, some individual tests were found predictive of driving ability in this study. The MSDSA Road Sign Recognition was the only significantly predictor of MSDSA total scores and classifications. The logistic regression model had an overall predictive accuracy of 83% (sensitivity for pass 92%, specificity 40%). Overall, 88% (22/25) of those who passed and 50% (2/4) of those failed were correctly classified by the model. Ideally, the model should have correctly predicted all individuals with MSDSA *fail* classifications. However, it confirmed previous findings that the Road Sign Recognition is highly and clinically relevant in the cognitive assessment of fitness to drive. A meta-analysis in

stroke suggested that it is the best predictor of on-road driving performance (Devos et al., 2011). This subtest requires quickly developing a strategy for matching common traffic situations with road signs. The correlation between MSDSA Road Sign Recognition and RDB Key Search subtests suggests that they both tap executive skills related to route planning. The Road Sign Recognition was also significantly associated with the MSDSA Design Learning, which is a test of visuospatial memory. The pattern of results confirms previous findings that the Road Sign Recognition assesses more than road sign knowledge and it requires additional cognitive abilities such as visual memory, mental speed and problem-solving (Radford & Lincoln, 2004).

In this study the MSDSA Information Processing subtest did not contribute to the overall prediction of MSDSA total scores or classifications. However, previous studies have used other tests to measure this cognitive domain and suggested a significant relationship between information processing skills and driving ability (Akinwuntan et al., 2012a; Kotterba, Orth, Eren, Fangerau, & Sindern, 2003; Schultheis et al., 2010; Shawaryn et al., 2002).

RDB subtests assessing attention (Es-Fs Visual and Divided) and verbal executive skills (Cards, Sorting, Comprehension) were the most frequently failed subtests. Multiple regression analysis indicated that attention, visuospatial and verbal executive skills as measured by the Es-Fs and Comprehension subtests explained 58% of the variance in RDB total scores. The strongest predictor was the Es-Fs subtest and previous studies that used cancellation tasks for assessing attention and visuospatial skills have reported similar results (Akinwuntan et al., 2012a; Lincoln & Radford, 2008). The RBD Comprehension subtest assesses verbal, executive and working memory skills and another study by Simms and O'Toole (1994) found that a similar subtest (Token Test) differentiated between good and poor drivers in a neurological group of mixed pathology.

Findings were consistent with previous research supporting the hypothesis that attention, speed of processing, visuospatial and executive skills are associated with driving ability in MS (Akinwuntan et al., 2012a; Schanke, Grismo, & Sundet, 1995; Schultheis et al., 2010). Poor performance on these tasks are common in MS (Chiaravallotti & DeLuca, 2008; Foong et al., 1997; Sartori & Edan, 2006).

Factors associated with MSDSA and RDB outcomes

Relationships between demographic, clinical and driving-related characteristics and the outcome variables were investigated. Results between sample characteristics and performance on both assessments were generally non-significant. The hypothesis that clinical variables will not be associated with participants' performance on the MSDSA and RDB was partially supported. Type and duration of MS were not significantly related to RDB and MSDSA outcomes. Greater physical disability was only associated with worse RDB total scores. Physical disability as measured by the GNDS may have contributed towards inconsistent findings. Although the GNDS was selected as a multi-domain measure for capturing all disabilities encountered in MS, it may have its limitations as a self-report measure. Other MS-specific disability measures have been used by previous studies and have been critisised for focusing either towards ambulatory (Expanded Disability Status Scale) or upper-lower limb and cognitive functions (MS-Functional Composite) (Kotterba et al., 2003; Gray & Butzkueven, 2008; Shawaryn et al., 2002).

Although the study tried to include participants at any stage of their MS and from a wide range of settings, it is acknowledged that the sample mostly included functionally independent individuals. Therefore, findings should be interpreted cautiously as relevant to drivers with MS with relatively preserved physical and cognitive functioning.

Previous studies have reported similar findings, but these also included individuals with mild to moderate disabilities (Akinwuntan et al., 2012a, 2012b; Schultheis et al., 2002). Patterns of physical deterioration in MS are unpredictable and not always consistent with cognitive decline (Chiaravallotti & DeLuca, 2008). The relationship between MS-related physical deficits, such as fatigue, spasticity, tremor and driving ability could be further investigated with an on-road test as these cannot be compensated with car adaptations (Marcotte et al., 2008).

A significant finding was the relationship between occupational driving and MSDSA performance. Participants who reported driving as part of their occupation were more likely to be classified as a *pass* and had better total scores on the MSDSA. However, similar findings were not found in relation to RDB outcomes. Moreover, no significant results were found regarding the performance of participants with an advanced driving qualification (n=3). On the contrary, Lundberg et al. (2003) found that professional drivers were more likely to pass the on-road test and fail the Nordic version of the Stroke Driver's Screening Assessment. Another study in people with dementia found that participants with an advanced driving qualification were safe to drive based on an on-road test and their performance was predicted by their cognitive results (Lincoln et al., 2010). These findings imply an interesting relationship between the effects of cognitive impairment on the driving ability of professional and skilled drivers. It may be that cognitive weaknesses in this group are compensated by a high level of driving competence. Therefore, the interplay between these factors should be considered when interpreting cognitive and on-road tests results in a clinical context.

Methodological considerations

Assessments used

The choice of cognitive tests was determined by theoretical and practical considerations. Few cognitive assessments have been proposed for assessing fitness to drive in people with MS with no sufficient evidence supporting their predictive validity. For instance, the tests identified by Schultheis et al. (2010) only marginally predicted the outcome of an on-road assessment and it was unclear whether the driving evaluator was blind to the results of the cognitive tests. Akinwuntan et al. (2012a, 2012b) suggested that the Stroke Driver's Screening Assessment can be used either on its own or in combination with other tests for predicting driving safety in this population. However, these papers were recently published and only investigated the predictive validity of the Dot Cancellation and Road Sign Recognition MSDSA subtests. The remaining two MSDSA subtests (i.e., Design Learning and Information Processing) were excluded because they are not currently used in the United States, whereas these are widely used in the UK.

Statistical analyses and sample size

The recruitment of a larger clinical sample was constrained by time and resources. The attrition rate was very low as only one participant decided to drop out and the achieved sample size was to a similar standard of most studies on fitness to drive in MS (Kotterba et al., 2003, n=31; Marcotte et al., 2008, n=17; Schultheis et al. 2001, n=28; Shawaryn et al., 2002, n=29). The optimum sample size was determined by an *a priori* power calculation, which was performed for achieving statistical power and for avoiding Type II errors. Kappa coefficient sample size requirements and limitations were considered, but it is the most appropriate measure of agreement (Sim & Wright, 2005). Moreover, the assumptions of statistical tests that are sensitive to small N and skewed data were not violated and statistical values for smaller sample sizes were

reported. Several independent variables were investigated to explore the relationship between sample characteristics and the outcomes of both batteries. Post-hoc procedures were not performed as most results were non-significant. The possibility of Type I errors was addressed by using Bonferroni corrections to set the critical value of significance based on the number of comparisons.

Ethical issues

Participation or non-participation to the study could introduce selection bias and affect the findings of any clinical research (Kendall, Butcher, & Holmbeck, 1999). Despite making cautious recommendations that there is not enough research evidence to support the validity of the two tests, the conditions of ethical approval to pass on results to clinicians appeared to affect recruitment numbers. It is likely that participants recruited were confident that their cognition is not impaired to an extent that could affect their driving ability. Some individuals who did not take part were concerned about what implications this study may have on future decisions about their fitness to drive. This may have contributed to a sample biased towards more participants without cognitive impairment and could justify the very small number of participants with *fail* classifications.

Theoretical and clinical implications

Most research on driving in neurological conditions has been informed by Michon's (1979) model. This model suggested a three-level hierarchy of driving performance divided into *strategic* (planning), *tactical* (manoeuvring) and *operational* (controlling) behaviours. In this study, results suggested that attention, visuoperceptual and executive skills should be considered when assessing cognitive function in relation to driving competency in the MS population. Figure 4 represents individual subtests in relation to this model. Attention and visuoperceptual difficulties are associated with reduced driving ability at the *operational* level, while executive difficulties are associated with

reduced ability to perform compensatory behaviours at the *tactical* and *strategic* level. This is consistent with findings on neuropsychological function and driving ability in people with Parkinson's disease (Stolwyk, Charlton, Triggs, Iansek, & Bradshaw, 2006).

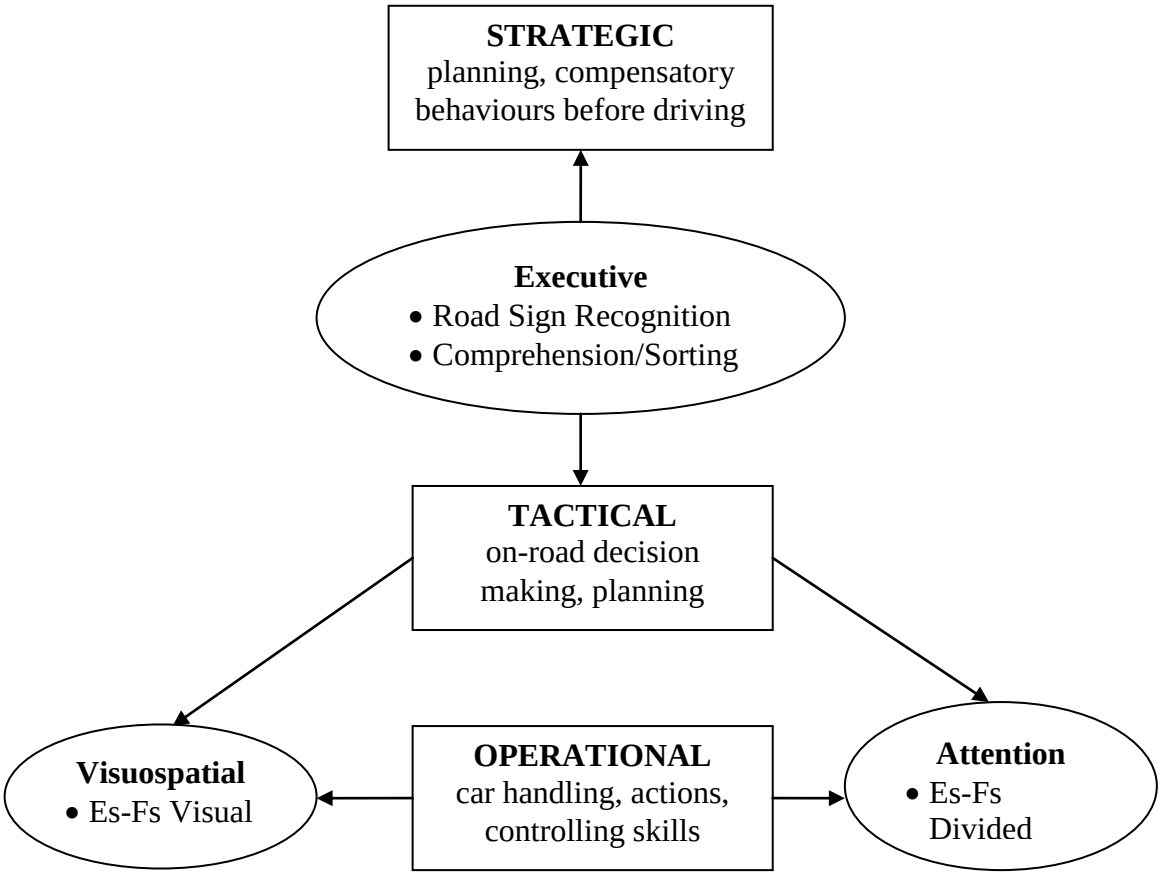

Figure 4. Cognitive Tests based on a Model of Driving Performance (Michon, 1979)

The unpredictability of progression rates and variable effects of different MS subtypes could not simply indicate when someone should be referred for an on-road assessment. Molnar et al. (2006) suggested that in progressive neurological conditions, decisions about fitness to drive should be tailored to each individual. Chipcase, Lincoln, and Radford (2003) suggested that people with MS require ongoing advice due to the fluctuating and progressive nature of their condition. The study further highlighted the need to identify brief and accessible screening measures of driving ability in this population.

The MSDSA is a short, cost-effective and MS-specific screening battery. In clinical work, it is important to recognise unsafe drivers who continue to drive as they may pose a risk for themselves and others (BPS, 2001). An over-cautious predictive battery, such as the MSDSA, is more preferable to one that uses lenient criteria and tends to miss *fail* classifications. Neuropsychological batteries ultimately aim to complement and inform the on-road assessment rather than to replace it. It is suggested that the more stringent cut-off criterion ≥6 should be considered when using the RDB in people with MS. It appears reasonable to offer patients with borderline scores a more detailed assessment and ideally an on-road assessment (Lundberg et al., 2003).

Ethical issues are raised, so it is important to consider and balance the risks of any decisions before allowing individuals to drive or stopping them from doing so. Martin, Marottoli, and O'Neill (2009) concluded that the cognitive test that most strongly predicted on-road performance in people with dementia could potentially prevent six future crashes, but at the price of stopping 121 safe people from driving. Therefore, further research makes this process more evidence-based and helps clinicians to make recommendations based on validated and reliable assessments.

Future research

This study is viewed as pilot and feasibility work that could inform future research. The psychometric properties of MSDSA and RDB need to be further explored and a larger study could examine the factor structure of the two batteries in a cohort with a range of physical and cognitive difficulties. It was expected that the MSDSA and RDB would have *very good* agreement, but there were some discrepant results for participants with *fail* classifications. Consequently, it is recommended to further validate these batteries against an on-road test in a representative sample of individuals with MS. Future studies need to consider the practical, legal, and ethical implications of on-road assessments, which can create obstacles in the design and recruitment stages both for

participants and researchers (Martin et al., 2009). There is a need for a meta-analysis of the data from the small-scale studies conducted so far. Clinically relevant cut-off scores need to be determined for cognitive tests used, which fits with recommendations for future research in Parkinson's disease (Klimkeit, Bradshaw, Charlton, Stolwyk, & Georgiou-Karistianis, 2009).

Conclusions

MSDSA and RDB showed moderate inter-rater agreement. The MSDSA was more sensitive in identifying *fail* classifications compared to the RDB, which is the screening measure used by many specialist driving centres in the UK. Although it may be difficult to clearly determine which cognitive tests are best able to predict driving abilities, the results indicated that a combination of tests can be used as screening measures. Attention, information processing, visuoperceptual and executive skills were found important when assessing driving ability in people with MS. This study aimed at addressing some of the methodological limitations in previous studies, but future research is recommended in larger and more representative samples.

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Footnotes

[1] *Sensitivity* is the proportion of true positives and *Specificity* is the proportion of true negatives that are correctly identified by a test (Altman & Bland, 1994).

[2] z skewness formula= (skewness-0)/standard error of skewness.

[3] Bonferroni correction= level of significance/number of comparison groups.

Section Three: APPENDICES

Appendix Literature Review: Newcastle-Ottawa Scale

NEWCASTLE-OTTAWA QUALITY ASSESSMENT SCALE
CASE CONTROL STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability.

Selection

1) Is the case definition adequate?
   a) yes, with independent validation ✸
   b) yes, eg record linkage or based on self reports
   c) no description

2) Representativeness of the cases
   a) consecutive or obviously representative series of cases ✸
   b) potential for selection biases or not stated

3) Selection of Controls
   a) community controls ✸
   b) hospital controls
   c) no description

4) Definition of Controls
   a) no history of disease (endpoint) ✸
   b) no description of source

Comparability

1) Comparability of cases and controls on the basis of the design or analysis
   a) study controls for _____ (Select the most important factor.) ✸
   b) study controls for any additional factor ✸ (This criteria could be modified to indicate specific control for a second important factor.)

Exposure

1) Ascertainment of exposure
   a) secure record (eg surgical records) ✸
   b) structured interview where blind to case/control status ✸
   c) interview not blinded to case/control status
   d) written self report or medical record only
   e) no description

2) Same method of ascertainment for cases and controls
   a) yes ✸
   b) no

3) Non-Response rate
   a) same rate for both groups ✸
   b) non respondents described
   c) rate different and no designation

NEWCASTLE-OTTAWA QUALITY ASSESSMENT SCALE
COHORT STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability

Selection

1) Representativeness of the exposed cohort
   a) truly representative of the average _____ (describe) in the community ✸
   b) somewhat representative of the average _____ in the community ✸
   c) selected group of users eg nurses, volunteers
   d) no description of the derivation of the cohort

2) Selection of the non exposed cohort
   a) drawn from the same community as the exposed cohort ✸
   b) drawn from a different source
   c) no description of the derivation of the non exposed cohort

3) Ascertainment of exposure
   a) secure record (eg surgical records) ✸
   b) structured interview ✸
   c) written self report
   d) no description

4) Demonstration that outcome of interest was not present at start of study
   a) yes ✸
   b) no

Comparability

1) Comparability of cohorts on the basis of the design or analysis
   a) study controls for _____ (select the most important factor) ✸
   b) study controls for any additional factor ✸ (This criteria could be modified to indicate specific control for a second important factor.)

Outcome

1) Assessment of outcome
   a) independent blind assessment ✸
   b) record linkage ✸
   c) self report
   d) no description

2) Was follow-up long enough for outcomes to occur
   a) yes (select an adequate follow up period for outcome of interest) ✸
   b) no

3) Adequacy of follow up of cohorts
   a) complete follow up - all subjects accounted for ✸
   b) subjects lost to follow up unlikely to introduce bias - small number lost - > ____ % (select an adequate %) follow up, or description provided of those lost) ✸
   c) follow up rate < ____% (select an adequate %) and no description of those lost
   d) no statement

Appendix A1: Scientific Approval

The University Of Sheffield.

Department Of Psychology.
Clinical Psychology Unit.

Doctor of Clinical Psychology (DClin Psy) Programme
Clinical supervision training and NHS research training & consultancy.

Clinical Psychology Unit
Department of Psychology
University of Sheffield
Western Bank
Sheffield S10 2TP UK

Telephone: 0114 2226570
Fax: 0114 2226610
Email: dclinpsy@sheffield.ac.uk
Please address any correspondence to Ms. Christie Harrison, Research Support Officer

31st March 2011

To: Research Governance Office

Dear Sir/Madam,

RE: Confirmation of Scientific Approval of enclosed Research Project

Project title: Validation of two neuropsychological batteries for assessing fitness to drive in people with Multiple Sclerosis

Investigators: Eirini Kontou (DClin Psy Trainee, University of Sheffield); Dr Claire Isaac (Academic Supervisor, University of Sheffield); Prof Nadina Lincoln (Academic Supervisor, University of Nottingham).

I write to confirm that the enclosed proposal forms part of the educational requirements for the Doctoral Clinical Psychology Qualification (DClin Psy) run by the Clinical Psychology Unit, University of Sheffield.

Three independent reviewers appointed by the Clinical Psychology Unit Research Sub-committee have scientifically reviewed it.

I can confirm that all necessary amendments have been made to the satisfaction of the reviewers, who are now happy that the proposed study is of sound scientific quality. Consequently, the University will also be happy to indemnify it and to act as research sponsor once ethical approval has been gained.

Given the above, I would remind you that the Unit already has an agreement with your office to exempt this proposal from further scientific review. However, if you require any further information, please do not hesitate to contact me.

Yours sincerely

Dr. Andrew Thompson
Director of Research Training

Cc. Eirini Kontou; Dr Claire Isaac

Appendix A2: Ethical Approval

NHS
National Research Ethics Service
NRES Committee East Midlands - Nottingham 1
The Old Chapel
Royal Standard Place
Nottingham
NG1 6FS

Telephone: 0115 8839390 (Direct Line)
Facsimile: 0115 9123300

16 August 2011

Dr Claire Isaac
Senior Clinical Psychologist
Clinical Neuropsychology Services
12 Claremont Crescent Glossop Road
Royal Hallamshire Hospitals
Sheffield
S10 2JF

Dear Dr Isaac

Study title: **Validation of two neuropsychological batteries for assessing fitness to drive in people with multiple sclerosis**
REC reference: **11/EM/0282**

The Research Ethics Committee reviewed the above application at the meeting held on 09 August 2011. Thank you for sending Dr Eirini Kontou (Student) to discuss the study.

Ethical opinion

Discussion with Researcher

- The Researcher was asked for clarification as to how potential participants are approached, as the Committee stated that they believed the patients from Sheffield and Nottingham to be approached by the clinical team, and then the Researcher will contact them. Those in Derby will be contacted by the Researcher. The Researcher confirmed that this was incorrect with reference to the Derby site. She confirmed that a contact from the Derby Mobility Centre will give out the information, as they will have already been referred there.

- The Committee asked how many participants are needed in total for the study. The Researcher confirmed that they require 40 in total; 15 from the Mobility Centre.

- The Committee asked whether there should be a duty of care to report any failed tests to the DVLA. The Researcher stated that no one will be going for the driving assessment unless they have already completed the questionnaires. She also stated that there is not enough evidence on the validity of the tests. If they do fail the tests this will be discussed with and explained to them. The Researcher also stated that it is research information and there would be much information missing on the clinical health of the participant. However, most patients do comply with the results of the tests if they significantly fail both. The Committee agreed that this was satisfactory as the battery of tests will only prove cognitive impairment and not necessarily that the patient is unfit to drive.

- The Committee informed the Researcher that it would not be common practice to send out the Consent Form for completion together with the Invitation Letter, Participant Information Sheet and Reply Slip as the potential participant would not have had the opportunity to discuss the study with the Researcher prior to completing and signing the Consent Form. The Committee did state that the Consent Form could still be sent out, but state in the Invitation Letter that this is for information and will be signed once the study has been discussed with the Researcher face-to-face.

The members of the Committee present gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Ethical review of research sites

NHS Sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

Additional conditions:-

1. The Committee agreed that it should be made clear in the Participant Information Sheet that 'all test results will be reported to the clinical team'.

2. The Invitation Letter should be revised to state that a 'Consent Form is included for information and will be signed when they meet with the Researcher, if they wish to take part'. It should also be revised to state that they need only 'return the reply slip'.

It is responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

You should notify the REC in writing once all conditions have been met (except for site approvals from host organisations) and provide copies of any revised documentation with updated version numbers. Confirmation should also be provided to host organisations together with relevant documentation

Approved documents

The documents reviewed and approved at the meeting were:

Document	*Version*	*Date*
Covering Letter		25 July 2011
Investigator CV	Claire Isaac	
Investigator CV	Dr Eirini Kontou	25 July 2011
Letter of invitation to participant	2	01 February 2011
Other: Investigator CV	Professor Nadina Lincoln	01 May 2009
Other: Data Collection Form	2	01 February 2011
Other: Project Costings Form		25 February 2011
Other: Proposed Research Timetable	2	01 February 2011
Other: Research Contract and Guidelines for Home Visits		
Participant Consent Form: Part 1	2	01 February 2011
Participant Consent Form: Part 2	2	01 February 2011
Participant Information Sheet: Part 1	2	01 February 2011
Participant Information Sheet: Part 2	2	01 February 2011
Protocol	3	01 February 2011
Questionnaire: Guy's Neurological Disability Scale		
Questionnaire: Rookwood Driving Battery		
Questionnaire: Driving Assessment Score Sheet		
REC application	78768/234834/1/251	22 July 2011
Referees or other scientific critique report		31 March 2011
Summary/Synopsis		

Membership of the Committee

The members of the Ethics Committee who were present at the meeting are listed on the attached sheet.

Professor Cris Constantinescu informed the Committee that he is a Co-Investigator in this study. However, he has had little involvement with the writing of the protocol/application. The Committee agreed that he need not leave the room while the study was reviewed. However, they agreed that he could not vote on the outcome of the review.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

Feedback

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

Further information is available at National Research Ethics Service website > After Review

11/EM/0282	**Please quote this number on all correspondence**

With the Committee's best wishes for the success of this project

Yours sincerely

P. Wheat

pp **Reverend Keith Lackenby**
Vice-Chair

Email: trish.wheat@nottspct.nhs.uk

Enclosures: *List of names and professions of members who were present at the meeting and those who submitted written comments*
"After ethical review – guidance for researchers"

Copy to: *Dr Eirini Kontou - Student*

Dr Ramila Patel, Sheffield Teaching Hospitals

Tanya Loughran, Sheffield Teaching Hospitals

Appendix A3: R&D Approval

Ref: STH16150/RP

Sheffield Teaching Hospitals NHS
NHS Foundation Trust

03 Nov 11

Dr Claire Isaac
Clinical Neurophysiologist
The University of Sheffield
Department of Psychology
Clinical Psychology Unit
Psychology Building
302 Western Bank
Sheffield, S10 2TP

Dear Dr Isaac,

Authorisation of Project

STH ref: STH16150
Study title: Validation of Two Neuropsychological Batteries for Assessing Fitness to Drive in People with Multiple Sclerosis

Chief Investigator: Dr Claire Isaac, The University of Sheffield
Principal Investigator: Dr Claire Isaac, The University of Sheffield

Sponsor: Sheffield Teaching Hospitals NHS Foundation Trust
Funder: Unfunded

The Research Department has received the required documentation for the study as listed below:

1.	**Sponsorship IMP studies (non-commercial)** **Sponsorship responsibilities between institutions** **Responsibilities of investigators** **Monitoring Arrangements**	N/A N/A N/A N/A
2.	**STH registration document: completed and signed**	NHS REC Form, v3.2: D Patel, 22 Jul 11
3.	**Evidence of favourable scientific review**	Clinical Psychology Unit, UoS: A Thompson, 31 Mar 111
4.	**Protocol – final version**	Version 4.0, 01 Sep 11
5.	**Participant Information sheet – final version**	
	Part 1 Part 2	Version 3.0, 01 Sep 11 Version 3.0, 01 Sep 11
6.	**Consent form – final version**	
	Part 1 Part 2	Version 3.0, 01 Sep 11 Version 3.0, 01 Sep 11
7.	**Signed letters of indemnity**	N/A
8.	**ARSAC / IRMER certificate**	N/A

9.	**Evidence of hosting approval from STH directorate**	STH Finance Form: G Venables, undated
10.	**Evidence of approval from STH Data Protection Officer**	N/A
11.	**Letter of approval from REC**	East Midlands – Nottingham 1 REC, REC Ref: 11EM/0282 30 Sep 11
12.	**Proof of locality approval**	STH R&D
13.	**Clinical Trial Authorisation from MHRA**	N/A
14.	**Honorary Contract**	N/A
15.	**Associated documents**	
	Letter of invitation	Version 3.0, 01 Sep 11
16.	**Signed financial agreement/contract**	STH Finance Form: L Fraser, 02 Nov 11

The project has been reviewed by the Research Department and authorised by the Director of R&D on behalf of STH NHS Foundation Trust to begin.

Yours sincerely

Professor S Heller
Director of R&D, Sheffield Teaching Hospitals NHS Foundation Trust
Telephone +44 (0) 114 2265934
Fax +44 (0) 114 2265937

Nottingham University Hospitals NHS
NHS Trust

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www.nuh.nhs.uk
nuhrise.org

Professor Chris S Constantinescu
Division of Clinical Neurology, Room B31
Medical School
Queen's Hospital Campus
Nottingham University Hospital, Nottingham
Derby Road

17 November 2011

Dear Professor Chris S Constantinescu

ID: 11NS017 **Validation of two neuropsychological batteries for assessing fitness to drive in people with multiple sclerosis**

The R&I Department has considered the following documents:

IRAS NHS R&D form version 3.2
IRAS NHS SSI Form version 3.2
Letter of invitation to participant version 3 dated 01/09/11
Participant Consent for: Part 1 version 3 dated 01/09/11
Participant consent form: Part 2 version 3 dated 01/09/11
Participant information sheet: Part 1 version 3 dated 01/09/11
Participant information sheet: Part 2 version 3 dated 01/09/11
Protocol version 4 dated 01/09/11
Data collection form version 2 dated 01/02/11
Proposed Reseach Timetabel version 2 dated 01/02/11
Questionnaire: Guy's Neurological Disability Scale
Questionnaire: Rookwood Driving Battery
Questionnaire: Driving Assessment score sheet

Your study now has R&I approval, on the understanding and provision that you will follow the conditions set out below.

Conditions of Approval

That you:

1. Comply with all relevant laws, regulations and codes of practice applicable to the trial including but not limited to, the UK Clinical Trials Regulations, Medicines for Human Use (Clinical Trial) Regulations 2004, principles of Good Clinical Practice, the World Medical Association Declaration of Helsinki entitled 'Ethical Principles for Medical Research Involving Human Subjects' (1996 version), the Human Rights Act 1998, the Data Protection Act 1998 the Medicines Act 1968, the NHS Research Governance Framework for Health and Social Care (version 2 April 2005). Should any of these be revised and reissued the latest version of the relevant laws and regulations will apply. Copies of the regulations are available from the R&I Office or via the R&I website http://nuhrise.org

2. For NUH sponsored studies accept the responsibilities as outlined in the "Clinical Trial Delegation of Sponsorship responsibilities to Chief Investigator? agreement.

3. Request written approval from the R&I department, Ethics Committee and MHRA (as appropriate) for

4. Ensure all study personnel, not employed by the Nottingham University Hospitals NHS Trust hold either honorary contracts/letters of access with this Trust, before they have access to any patients or staff, their data, tissue or organs or any NUH facilities.

5. According to R&I SOP 11 - "Adverse Event Monitoring, Recording and Reporting for investigators" report any Serious Adverse Events to the R&I department.

6. According to R&I SOP 12 - "Protocol Violations and Serious Breach Reporting? report any Serious Breach of the UK Clinical Trial regulations in connection with the trial or Serious Breach of the protocol, immediately after becoming aware of the breach to R&I.

7. Complete Annual Safety, Progress reports and End of Study reports as required by R&I, Ethics Committee and the MHRA.

8. Notify R&I within 7 calendar days of the first patient or healthy volunteer recruited onto the study, as well as the detail of the specific recruitment date. Please email the recruitment notification to rdmon@nuh.nhs.uk. At the discretion of this R&I office your study may be closed down if you fail to recruit within 12 months of the date of this R&I approval letter.

9. For GTAC-approved studies, the R&I approval letter should be forwarded to GTAC via the sponsor. GTAC should then issue a site authorisation letter which must be received by each site prior to recruitment commencing. A copy of the letter must be forwarded to R&I.

This approval letter constitutes a favourable Site Specific Assessment (SSA) for this site.

Please note that the R&D department has a database containing study related information, and personal information about individual investigators e.g. name, address, contact details etc. This information will be managed according to the principles established in the Data Protection Act.

Yours sincerely,

Dr Brian Thomson / Dr Maria Koufali
Director of R&I / Deputy Director Research and Innovation
cc Nottingham Research Ethics Committee

Appendix B: Feedback Letters

The University Of Sheffield.

Department Of Psychology.
Clinical Psychology Unit.

Doctor of Clinical Psychology (DClin Psy) Programme
Clinical supervision training and NHS research training & consultancy.

Clinical Psychology Unit
Department of Psychology
University of Sheffield
Western Bank
Sheffield S10 2TN UK

Tel: 0114 222 6650

Date

Dear

Re:

Thank you for inviting Mr/Mrs/Ms to take part in our research study on the validation of two neuropsychological batteries for assessing fitness to drive in people with multiple sclerosis.

Mr/Mrs/Ms has agreed to take part and he/she has now completed the *Rookwood Driving Battery* and the *MS-Driver's Screening Assessment* which have previously been used to assess cognitive abilities that could determine fitness to drive.

He/she received a PASS score on both neuropsychological batteries which indicated that his/her cognitive abilities are such that driving is feasible. The results of these cognitive assessments have been discussed with Mr/Mrs/Ms.

Please note that these screening assessments have been validated in small samples of people with multiple sclerosis. Therefore, it is recommended that the above results would be used to supplement additional clinical information about an individual's fitness to drive.

If you have any questions or you would like to discuss this letter further, then please do not hesitate to contact us.

Yours sincerely,

Eirini Kontou

Trainee Clinical Psychologist

supervised by Dr Claire Isaac and Professor Nadina Lincoln

Copy to:

The University Of Sheffield.

Department Of Psychology.
Clinical Psychology Unit.

Doctor of Clinical Psychology (DClin Psy) Programme
Clinical supervision training and NHS research training & consultancy.

Clinical Psychology Unit
Department of Psychology
University of Sheffield
Western Bank
Sheffield S10 2TN UK

Tel: 0114 222 6650

Date

Dear

Re:

Thank you for inviting Mr/Mrs/Ms to take part in our research study on the validation of two neuropsychological batteries for assessing fitness to drive in people with multiple sclerosis.

Mr/Mrs/Ms has agreed to take part and he/she has now completed the *Rookwood Driving Battery* and the *MS-Driver's Screening Assessment* which have previously been used to assess cognitive abilities that could determine fitness to drive.

He/she received a PASS on the RDB and FAIL on the MSDSA. Therefore, if there are any further concerns it is recommended to refer Mr/Mrs/Ms for an on-road assessment. The results of these cognitive assessments have also been discussed with Mr/Mrs/Ms and he/she was advised to discuss this further with you or his/her GP.

Please note that these screening assessments have been validated in small samples of people with multiple sclerosis. Therefore, it is recommended that the above results would be used to supplement additional clinical information about an individual's fitness to drive.

If you have any questions or you would like to discuss this letter further, then please do not hesitate to contact us.

Yours sincerely,

Eirini Kontou
Trainee Clinical Psychologist
supervised by Dr Claire Isaac and Professor Nadina Lincoln

Copy to:

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SUMMARY OF COGNITIVE ASSESSMENT SCORES

Name: **Date of Birth:** **Date of Assessment:**

ROOKWOOD DRIVING BATTERY

	Raw Scores	Profile Score
Shape Perception		
Visual Spatial Skills		
Position Discrimination		
Cube Analysis		
Attention		
Visual		
Divided		
Praxis Skills		
Copy, Gesture & Objects		
Tapping & Sequencing		
Executive Functioning		
Key Search Test		
Action Program Test		
Rule Shifts Cards Test		
Sorting Test		
Comprehension		

Overall Score RDB:

MS-DRIVER'S SCREENING ASSESSMENT

Stroke Drivers' Screening Assessment

Dot Cancellation	Time
	Errors
	False Positives

Road Sign Recognition

Adult Memory and Information Processing Battery

		Raw Scores	Percentile
Design Learning	Total		
	Recall		
	Errors		
Information Processing	Task B total		
	Task B errors %		
	Task B speed		
	Task B adjusted		

Overall Score MSDSA: Pass Equation Score
Fail Equation Score

Appendix C1: Invitation Letter and Reply Slip

The University Of Sheffield.

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Clinical Psychology Unit.

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Department of Psychology
University of Sheffield
Western Bank
Sheffield S10 2TN UK

INVITATION LETTER

Date

Dear

Re: Research Study on Cognition and Fitness to Drive in Multiple Sclerosis

We would like to invite you to take part in a research study looking at two cognitive assessments that are assessing safety to drive in people with multiple sclerosis. This research project is conducted as part of a clinical psychology doctorate programme at the University of Sheffield with a collaborating researcher from the University of Nottingham.

If you are interested to take part, then please only complete the reply slip and return it to us using the pre-paid envelope provided. The researchers will contact you after they receive this to arrange meeting you to further discuss the purpose of this study before you decide to take part. Please find enclosed an Information Sheet for Participants summarising the purpose of this research study and a Consent Form which is included for information as this will be signed when you meet with the researcher.

If you have any questions, please do not hesitate to leave a message with our research support officer for the investigator (Eirini Kontou) on 0114 222 6650 to call you back as soon as possible. If you wish, you could also contact any other member of the research team (see information sheet for additional contact details).

Thank you for taking time to read this.

Kind regards,
Eirini Kontou
Trainee Clinical Psychologist
supervised by Dr Claire Isaac and Professor Nadina Lincoln

Version 3-August 2011

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REPLY SLIP

If you would like the researchers to contact you to further discuss this study and you are interested to take part or find out more about the study, then please use this reply slip to write you contact details and return this to us using the pre-paid envelope provided.

Name: _____

Address: _____

Telephone number: _____

Version 3-August 2011

Appendix C2: Information Sheet

The University Of Sheffield.

Department Of Psychology.
Clinical Psychology Unit.

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University of Sheffield
Western Bank
Sheffield S10 2TN UK

INFORMATION FOR PARTICIPANTS

Validation of Two Neuropsychological Batteries for Assessing Fitness to Drive in People with Multiple Sclerosis: PART 1

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of this study?
At present everyone with multiple sclerosis is required to notify the DVLA if they wish to continue to drive. However there are inconsistencies in the methods used to decide whether a person with multiple sclerosis may continue to drive. The purpose of this project is to compare two existing neuropsychological batteries which assess cognitive abilities, such as attention, concentration and awareness of space, which have previously been used to determine fitness to drive in people with multiple sclerosis.

Why have I been chosen?
We are asking people with a diagnosis of multiple sclerosis, who have been driving in the past three years, to take part in this study which involves completing two cognitive assessments.

Do I have to take part?
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and asked to sign a consent form which you will be also be given a copy. Even if you decide to take part you are still free to withdraw at any time, without giving a reason, and if you wish all information about you will be destroyed. This will not affect the standard of care you receive.

What will happen if I take part?
If you agree to take part you will be asked to undertake some pencil and paper type tests of concentration, reasoning, memory and attention. A trained researcher will complete the assessments with you which will take between one and two hours. You may take breaks between tests if you wish. The testing can be split into two or more sessions if you find that you get tired or do not wish to do too much at one time. The researcher will visit you either at your own home or see you when you attend a hospital appointment.

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Department of Psychology
University of Sheffield
Western Bank
Sheffield S10 2TN UK

What is being tested?
The results of the two cognitive assessments will be compared to assess your cognitive abilities in relation to driving performance and to find out whether these paper and pencil tests could be used as preliminary screening measures to identify those people with multiple sclerosis who may have difficulty driving and who may need on-road assessment to see if they are safe to drive.

What are the possible benefits of taking part?
We hope that information gathered from this study will help individuals with MS in the future. You will also be given the opportunity to receive a summary of your abilities on all the cognitive tests, by indicating this on your consent form. If you want you may discuss this information with your clinical team, who may retain and use this information on future decisions about your fitness to drive.

What are the possible disadvantages and risks of taking part?
The researchers will report all test results to your clinical team. If you fail both tests, this may suggest that you have cognitive difficulties who may affect your fitness to drive and therefore we will advise you to further discuss this with your GP and/or Consultant Neurologist. In the unlikely event that you fail significantly on both cognitive assessments, sharing your test results with your clinicians may influence future decisions about your fitness to drive.

What if relevant new information becomes available?
Sometimes during the course of a research project, new information becomes available. If this happens, the researchers will tell you about it and discuss whether you want to continue in the study. If you decide to continue in the study you will be asked to sign an updated consent form.

What if there is a problem?
If you have a concern about any aspect of this study, you should ask to speak with principal investigator or the project supervisors who will do their best to answer your questions. If this is not satisfactory, you can use the University complaints procedure and contact Dr David Fletcher, Registrar and Secretary's Office, University of Sheffield, Firth Court, Western Bank, Sheffield S10 2TN. Contact number: 0114 222 1100.

Information on the NHS formal complaints procedure is also available to you and you can do this through the Nottingham University Hospitals Patient Advice and Liaison (PALS) service on 08001830204 (QMC campus) or through the Sheffield Teaching Hospitals Patient Service (PST) on 0114 2712400.

The University Of Sheffield.

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Clinical Psychology Unit.

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Department of Psychology
University of Sheffield
Western Bank
Sheffield S10 2TN UK

Will my participation in this study be kept confidential?
All information that is collected about you during the course of the research will be kept strictly confidential. The procedures used will comply with the Data Protection Act 1998 and all information will be stored in a locked filing cabinet and only members of the research team will have access to the data. Your test results will also be reported to a member of your clinical team. The information will be retained for 5 years and then disposed securely. We will also check your medical records to obtain information about your MS diagnosis. No other aspects of your medical records will be reviewed.

What will happen to the results of the research study?
We intend to publish the results of this research in a scientific journal and to present the findings at professional conferences. If you would like to receive the published results, then please tell the researcher. You will not be identified in any report or publication.

Who is organising and funding the research?
The research is being conducted by Eirini Kontou as part of a clinical psychology training programme at the University of Sheffield. The research is also supported by University of Nottingham.

Who has reviewed the study?
This study has been reviewed and given a favourable opinion by Nottingham 1 Research Ethics Committee and the relevant NHS Research & Development Departments.

If you would like any further information or there is anything you do not understand please contact a member of the research team listed below.

<u>Investigators</u>

Dr Eirini Kontou 0114 222 6650 (only for messages)
Trainee Clinical Psychologist
University of Sheffield

Prof. Nadina Lincoln 0115 951 5315
Professor of Clinical Psychology
University of Nottingham

Dr Claire Isaac 0114 222 6639
Clinical Psychologist
University of Sheffield

Thank you for taking time to read this. If the information has interested you and you are considering participation, please read and sign the consent form

Appendix C3: Consent Form

The University Of Sheffield.

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Clinical Psychology Unit.

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Department of Psychology
University of Sheffield
Western Bank
Sheffield S10 2TN UK

CONSENT FORM

Validation of Two Neuropsychological Batteries for Assessing Fitness to Drive in People with Multiple Sclerosis: PART 1

Investigators: Dr Eirini Kontou, Dr Claire Isaac, & Professor Nadina Lincoln

Centre Number: ☐ Study Number: ☐

The participant should complete the whole sheet himself/herself

Please initial box

1. I confirm that I have read and understand the information sheet dated Sept 2011 (version 3) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that relevant sections of any of my medical notes and data collected during the study, may be looked at by responsible individuals from Sheffield and Nottingham universities, from regulatory authorities or from the NHS Trust, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records. ☐
4. I would like to receive a copy of my tests results. ☐
5. I agree to take part in the above study. ☐

Please write your full name in block capitals and sign below to indicate your willingness to take part in this study.

Name of Participant	Signature	Date
Name of Researcher	Signature	Date

Version 3-September 2011

Appendix D: Data Collection Form

Data Collection Form

	Yes	No
• **Information Sheet read and discussed**	☐	☐
• **Consent Form signed**	☐	☐
• **Cognitive Assessments completed**	☐	☐

Participant Details

Name: _____ Study ID No: _____

Recruitment Centre: Sheffield ☐ Nottingham ☐

Referral Source: _____

Contact Details

Address: _____

_____

Tel No: _____

Personal Details

Date of Birth: _____ (Age :_____)

Gender:_____

Occupation: _____

Years in Education: _____

Medical Information

Date of Diagnosis: _____Type of MS: _____

Current Medication: _____

_____

Other Medical Conditions: _____

_____

Driving Information

Total years of driving: _____

Are you currently driving? YES ☐ NO ☐

Do you consider yourself to be a frequent ☐ average ☐ infrequent ☐ driver?

Frequency of Driving since MS diagnosis (circle): *Same* *Less* *More*

Do you have an advanced driving qualification? YES ☐ NO ☐

Does/did your occupation involve a lot of driving? YES ☐ NO ☐

Have you had an accident in the last 5 years? YES ☐ NO ☐

Have you had any driving offences over the past 5 years? YES ☐ NO ☐

If YES give details: _____

_____

Information only for *Part 2* of the study:

Date of driving assessment: _____

Referred to DMRC by: _____

Date of referral: _____

Copy of driving assessment report received? YES ☐ NO ☐

Assessments in Part 1 completed? YES ☐ NO ☐

NOTES:

_____

_____

_____

_____

_____

_____

_____

_____

Appendix E: MS-Driver's Screening Assessment

Multiple Sclerosis Driving Screening Assessment
(MSDSA; Lincoln & Radford, 2008)

SCORING SHEET

SDA: Dot Cancellation	[A] Time (secs): _____
	[B] Errors: _____
	[C] False positives: _____
SDA: Road Sign Recognition	[D] _____
AMIPB: Design Learning Total (A1-A5)	[E] _____
AMIPB: Information Processing Task B Adjusted Score	[F] _____

PASS EQUATION		FAIL EQUATION	
[A] _____ x 0.057	+	[A] _____ x 0.047	+
[B] _____ x 0.170	-	[B] _____ x 0.163	-
[C] _____ x 0.181	+	[C] _____ x 0.142	+
[D] _____ x 1.337	+	[D] _____ x 0.718	+
[E] _____ x 0.163	+	[E] _____ x 0.319	+
[F] _____ x 0.427	=	[F] _____ x 0.343	=
- 36.9260	=	- 28.595	=
TOTAL: _____		TOTAL: _____	

PASS ☐ FAIL ☐

Higher value indicates/predicts outcome of driving assessment

Appendix F: Rookwood Driving Battery

Appendix G: Guy's Neurological Disability Scale

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23 Garratt AM *et al.* (1993) The SF36 health survey questionnaire: an outcome measure suitable for routine use within the NHS? *BMJ* **306:** 1440–1444.

Appendix

Guy's Neurological Disability Scale

Instructions
The scale is designed to assess disability in patients with multiple sclerosis. It has 12 separate categories each with an interview and scoring section. The total GNDS score is the sum of the 12 separate scores. The questions are directed to assess the disability in the previous one month.

1. Cognitive disability:

A. Interview:

Do you have any problems with your memory or your ability to concentrate and work things out?
☐ yes ☐ no

Do your family or friends think that you have such a problem?
☐ yes ☐ no

If the answer to either question is 'yes':
Do you need help from other people for planning your normal daily affairs, handling money or making decisions?
☐ yes ☐ no

If 'yes': (To the examiner)
Is the patient orientated in time, place and person?
☐ yes, fully
☐ yes, partially*
☐ no, totally disorientated*

*If the patient is not fully orientated, all their answers should be verified by the main carer(s) whose answers should take precedence.

B. Scoring:

0–No cognitive problems.
1–Cognitive problems not noticeable to family or friends.
2–Cognitive problems noticeable to family or friends but not requiring help from others.
3–Cognitive problems requiring help from others for normal daily affairs; patient is fully orientated in time, place and person.
4–Cognitive problems requiring help from others for normal daily affairs; patient is not fully orientated.
5–Patient is completely disorientated in time, place and person.

2. Mood disability:

A. Interview:

Have you been feeling anxious, irritable, depressed, or had any mood swings during the last month?
☐ yes ☐ no

Are you taking any medications for such problem
☐ yes ☐ no

If the answer to the first question is 'yes':
Has the problem affected your ability to do *any* of your usual daily activities such as work, housework, or normal social activity with family and friends?
☐ yes ☐ no

If 'yes':
Has this problem been severe enough to prevent you from doing *all* your usual activities?
☐ yes ☐ no

Have you been admitted to hospital for treatment of your mood problem during the last month?
☐ yes ☐ no

B. Scoring:

0 – No mood problems
1 – Asymptomatic on current drug treatment.
2 – Mood problems present but not affecting the patient's ability to perform any of their usual daily activities.
3 – Mood problems affecting the patient's ability to perform some of their usual daily activities.
4 – Mood problems preventing the patients from doing all their usual daily activities.
5 – Mood problems requiring inpatient management.
X – Unknown (please score as the mean of the cognitive and fatigue disability scores rounded the nearest integer).

3. Visual disability:

A. Interview:

Do you have any problems with your vision that can't be corrected with ordinary glasses?
☐ yes ☐ no

If 'yes':
Can you read ordinary newspaper print (with ordinary glasses if worn, but not magnifying lenses)?
☐ yes ☐ no

If 'no':
Can you read large newspaper print?
☐ yes ☐ no

If 'no':
Can you count your fingers if you hold your hand out in front of you?
☐ yes ☐ no

If 'no':
Can you see your hand if you move it in front of you?
☐ yes ☐ no

B. Scoring:

0 – No visual problems.
1 – Visual problems (blurred vision, diplopia, scotomas) but patient is still able to read ordinary newspaper print.
2 – Unable to read ordinary newspaper print.
3 – Unable to read large newspaper print.
4 – Unable to count fingers if they hold their hand out in front of them.
5 – Unable to see hand movement if they move their hand in front of them.

4. Speech and communication disability:

A. Interview:

Do you have any problems with your speech?
☐ yes ☐ no

If 'yes':
Do you have to repeat yourself when speaking to your family or close friends?
☐ yes ☐ no

If 'yes':
Do you need to use sign language, or the help of your carer to make people understand you?
☐ yes ☐ no

If 'yes': (to the examiner)
Is the patient able to communicate effectively using these methods?
☐ yes ☐ no

B. Scoring:

0 – No speech problems.
1 – Speech problems which does not require the patient to repeat themselves when speaking to strangers.
2 – Speech problems which require the patient to repeat themselves when speaking to strangers.
3 – Speech problems which require the patient to repeat themselves when speaking to their family and close friends.
4 – Speech problems making speech difficult to understand; patient is able to communicate effectively by using sign language or the help of their carers.
5 – Speech problems making speech difficult to understand, patient is unable to communicate effectively by using sign language or the help of their carers.

5. Swallowing disability:

A. Interview:

Do you have to take care when swallowing solids or fluids?
☐ yes ☐ no

If 'yes':
Do you have to take care when swallowing with most meals?
☐ yes ☐ no

If 'yes':
Do you need a special diet such as soft or liquidated food to help with your swallowing?
☐ yes ☐ no

If 'yes':
Do you choke with most meals?
☐ yes ☐ no

If 'yes':
Do you have a feeding tube (nasogastric or gastrostomy tube)?
☐ yes ☐ no

B. Scoring:

0 – No swallowing problems.
1 – Needs to be careful when swallowing solids or liquids but not with most meals.
2 – Needs to be careful when swallowing solids or liquids with most meals; patient is able to eat food of normal consistency.
3 – Needs specially prepared food of modified consistency.
4 – Tendency to choke with most meals.
5 – Dysphagia requiring nasogastric or gastrostomy tube.

6. Upper limb disability:

A. Interview:

Do you have any problems with your hands or arms?
☐ yes ☐ no

If 'yes':
Do you have any difficulty in doing any of your zips *or* buttons?
☐ yes ☐ no

If 'yes':
Are you able to do *all* of your zips *and* buttons without help?
☐ yes ☐ no

Do you have any difficulty in tying a bow in laces or strings?
☐ yes ☐ no

If 'yes':
Are you able to tie a bow in laces or strings without help?
☐ yes ☐ no

Do you have any difficulty washing *and* brushing your hair?
☐ yes ☐ no

If 'yes':
Are you able to wash *and* brush your hair without help?
☐ yes ☐ no

Do you have any difficulty feeding yourself?
☐ yes ☐ no

If 'yes':
Are you able to feed yourself without help?
☐ yes ☐ no

If unable to do any of the functions listed:
Can you use your hands or arms for any other function?
☐ yes ☐ no

B. Scoring

0 – No upper limb problem.
1 – Problems in one or both arms, not affecting the ability to do any of the functions listed.
2 – Problems in one or both arms, affecting some but not preventing any of the functions listed.
3 – Problems in one or both arms, affecting all or preventing one or two of the functions listed.
4 – Problems in one or both arms preventing three or all of the functions listed.
5 – Unable to use either arm for any purposeful movements.

7. Lower limb disability:

A. Interview:

Do you have any problems with your walking?
☐ yes ☐ no

If 'yes':
Do you use a walking aid?
☐ yes ☐ no

If 'yes':
A. How do you *usually* get around outdoors?
☐ without aid
or ☐ with one stick or crutch *or* holding on to someone's arm
or ☐ with two sticks or crutches *or* one stick or crutch and holding on to someone's arm
or ☐ with a wheelchair

B. How do you *usually* get around indoors?
☐ without aid
or ☐ with one stick or crutch *or* holding on to someone's arm
or ☐ with two sticks or crutches *or* one stick or crutch and holding on to someone's arm
or ☐ with a wheelchair

If you use a wheelchair:
Can you stand and walk a few steps with help?
☐ yes ☐ no

B. Scoring

0 – Walking is not affected.
1 – Walking is affected but patient is able to walk independently.
2 – Usually uses unilateral support (single stick or crutch, one arm) to walk outdoors, but walks independently indoors.
3 – Usually uses bilateral support (two sticks or crutches, frame, or two arms) to walk outdoors, *or* unilateral support (single stick or crutch, or one arm) to walk indoors.
4 – Usually uses wheelchair to travel outdoors, *or* bilateral support (two sticks or crutches, frame, or two arms) to walk indoors.
5 – Usually uses a wheelchair indoors.

8. Bladder disablity

A. Interview:

Do you have any problems with your bladder?
☐ yes ☐ no

Are you taking any medications for such problems?
☐ yes ☐ no

If the answer to the first question is 'yes':
Do you have to rush to the toilet, go frequently, or have difficulty in starting to pass urine?
☐ yes ☐ no

Have you been incontinent in the last month?
☐ yes ☐ no

If 'yes':
Have you been incontinent in the last week?
☐ yes ☐ no

If 'yes':
Have you been incontinent every day?
☐ yes ☐ no

Do you use a catheter to empty your bladder?
☐ yes ☐ no

Do you need a permanent catheter in the bladder, or (*for men only*) do you use a sheath to collect your urine?
☐ yes ☐ no

B. Scoring:

0 – Normal bladder problems.
1 – Asymptomatic on current drug treatment.
2 – Urinary frequency, urgency, or hesitancy with no incontinence.
3 – Occasional urinary incontinence (once or more during the last month but not every week). *or* intermittent catheterisation without incontinence.
4 – Frequent urinary incontinence (once a week or more during the last month but not daily). *or* occasional urinary incontinence despite regular intermittent catheterisation.
5 – Daily urinary incontinence or permanent catheter (urethral/suprapubic) or penile sheath.

9. Bowel disability:

A. Interview:

Do you have any problems with your bowel movements?
☐ yes ☐ no

Are you no any medicines for such problems?
☐ yes ☐ no

If the answer to the first question is 'yes':
Do you suffer with constipation?
☐ yes ☐ no

If 'yes':
Do you need to take any laxatives or use suppositories for this?
☐ yes ☐ no

Do you usually use enemas?
☐ yes ☐ no

Do you usually evacuate your stools manually?
☐ yes ☐ no

Do you have to rush to the toilet to open your bowels?
☐ yes ☐ no

Have you had bowel accidents (been incontinent of faeces) in the last week?
☐ yes ☐ no
If 'yes':
Have you had bowel accidents every week?
☐ yes ☐ no

B. Scoring:

0 – No bowel problems.
1 – Asymptomatic on current drug treatment or constipation not requiring any treatment.
2 – Constipation requiring laxatives or suppositories *or* faecal urgency.
3 – Constipation requiring the use of enemas.
4 – Constipation requiring manual evacuation of stools *or* occasional faecal incontinence (once or more during the last month but not every week).
5 – Weekly faecal incontinence.

10. Sexual disabilities:

A. Interview:

The next set of questions relates to sexual function. Do you mind if I ask you about this?

☐ yes
☐ no
☐ not applicable (Celibate)

If the patient agrees:
Do you have any problems in relation to your sexual function?

☐ yes ☐ no

If 'yes':
Do you suffer with lack of sexual interest?

☐ yes ☐ no

Do you have any problems satisfying yourself or your sexual partner?

☐ yes ☐ no

Is your sexual function affected by any physical problem such as altered genital sensation, pain, or spasms?

☐ yes ☐ no

Do you have any problems with:
(*for men*): erection/ejaculation?
(*for women*): vaginal lubrication /orgasm?

☐ yes ☐ no

If physical or sexual problems are present:
Do any of these difficulties totally prevent your sexual activities?

☐ yes ☐ no

B. Scoring:

0 – Normal sexual functions *or* persons who are voluntarily celibate.
1 – Reduced sexual interest.
2 – Problems satisfying oneself or sexual partner.
3 – Physical problems interfering but not preventing sexual function.
4 – Autonomic problems interfering but not preventing sexual function.
5 – Physical or autonomic problems totally preventing sexual function.
X – Unknown (please score as the mean of the lower limb, bladder, and bowel disability scores rounded to the nearest integer).

11. Fatigue:

A. Interview:

Have you been feeling tired or getting tired easily during the last month?

☐ yes ☐ no

If 'yes':
Have you been feeling tired most days?

☐ yes ☐ no

Has this tiredness affected your ability to do *any* of your usual activities such as work, housework, or normal social activity with family and friends?

☐ yes ☐ no

If 'yes':
Has this tiredness been severe enough to prevent you from doing *all* of your usual activities?

☐ yes ☐ no

If 'yes':
Has the tiredness been severe enough to prevent you from doing *all* physical activities?

☐ yes ☐ no

B. Scoring:

0 – Absent
1 – Occasional fatigue (present some days).
2 – Frequent fatigue (present most days).
3 – Fatigue affecting the patient's ability to perform some of their usual daily activities.
4 – Fatigue preventing the patient from doing all their usual daily activities.
5 – Fatigue preventing the patient from doing all their physical activities.
X – Unknown (please score as the mean of the cognitive and mood disability scores rounded to the nearest integer).

12. Other disabilities:

A. Interview:

Do you have other problems due to MS such as pain, spasms, or dizziness which have not been mentioned so far?

☐ yes ☐ no

Are you taking any medicines for such problems?

☐ yes ☐ no

If the answer to either question is 'yes':
Please name your worst problem: .....

Has this problem affected your ability to do *any* of your usual daily activities?

☐ yes ☐ no

Has this problem been severe enough to prevent you from doing *all* your usual daily activities?

☐ yes ☐ no

Have you been admitted to hospital for treatment of this problem?

☐ yes ☐ no

B. Scoring:

0 – Absent.
1 – Asymptomatic on current drug treatment.
2 – Problems, present, but are not affecting the patient's ability to perform any of their usual daily activities.
3 – Problems affecting the patient's ability to perform some of their usual daily activities.
4 – Problems preventing the patient from doing all their usual daily activities.
5 – Problems requiring hospital admission for assessment or treatment.

Appendix H: Supplemental Statistical Tables

Table H1

Differences in MSDSA and RDB total scores according to order of administration and number of sessions

		MSDSA 1st (n=15)	**RDB 1st (n=14)**	**Mann-Whitney U Test**	**p-value**
MSDSA	Median	2.25	1.61	79.00	.27
	IQR	.03-4.98	.66-2.64		
RDB	Median	3.00	2.00	82.00	.31
	IQR	1.00-4.00	.50-3.00		
		One session (n=8)	**Two sessions (n=21)**	**Mann-Whitney U Test**	**p-value**
MSDSA	Median	1.20	3.00	55.00	.17
	IQR	-.11-2.41	1.50-4.00		
RDB	Median	2.25	2.00	55.50	.16
	IQR	1.32-4.37	1.00-3.00		

Table H2 *Correlations between RDB subtests*

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
RDB Total	**r**	-.19	**-.55****	**-.19*****	**-.72*****	.04	.08	-.07	-.28	**-.53****	**-.43***	**-.49****	**-.54****
1. Incomplete Letters		_	.00	-.03	.11	.04	-.00	.04	.16	.04	.06	-.09	.14
2. Position Discrimination			_	-.12	**.45***	.22	-.32	.07	.17	.27	.19	**.53****	.24
3. Cube Analysis				_	-.01	**-.43***	.16	-.19	.09	.12	-.30	-.03	-.04
4. Es-Fs Visual					_	-.08	.15	-.04	.14	.28	.21	**.41***	**.74*****
5. Key Search						_	-.28	.18	-08	-.13	.13	.23	-.26
6. Copying-Gestures							_	-.14	-.14	-.06	-.26	-.09	.32
7. Tapping-Sequencing								_	.13	.25	.24	-.23	.00
8. Sorting									_	.02	.07	.00	.27
9. Comprehension										_	.22	-.01	.19
10. Rule Shirt Cards											_	-.02	.01
11. Action Program												_	.25
12*.* Es-Fs Divided													_

*p<.05,**p<.01,***p<.001(two-tailed).

Table H3 *Correlations between RDB and MSDSA subtests*

		MSDSA Total	DC Time	DC Errors	DC False	RSR	DL	IP-A
RDB Total	**r**	**.37***	**.45***	**.39***	-.01	**-.54****	**-.44***	**-.70*****
Incomplete Letters		.08	-.06	-.13	.15	.27	.13	.08
Position Discrimination		.33	**-.47****	-.13	.02	**.45***	.11	**.44***
Cube Analysis		.05	-.06	-.09	-.02	.14	.20	.02
Es-Fs Visual		.23	**-.69*****	-.27	-.12	**.43***	**.46****	**.76*****
Key Search		.24	.12	.19	-.11	**.38***	-.14	-.15
Coping-Gestures-Objects		-.24	-.23	**.43***	.04	-.22	-.06	-.10
Tapping-Sequencing		-.06	-.01	-.36	.13	-.18	.04	.08
Sorting		.35	.06	**-.48****	.19	.27	.07	.35
Comprehension		.07	.23	-.28	.19	.17	**.39***	**.38***
Rule Shift Cards		.07	-.29	-.16	-.23	.14	.12	.25
Action Program		.24	-.31	.14	.07	.23	-.17	.20
Es-Fs Divided		.22	**-.59*****	-.23	-.03	.27	**.46****	**.77*****

Note. DC=Dot Cancellation; RSR=Road Sign Recognition; DL=Design Learning; IP-A=Information Processing-Adjusted.
*p<.05, **p<.01, ***p<.001 (two-tailed).

Table H4

Comparison of characteristics between MSDSA classifications

	Pass (n=24)	**Fail (n=5)**		
	Frequencies, *n*	**Frequencies, *n***	χ^2	**p-value**
Gender, female/male	15/9	2/3	.86	.62
Marital, married/divorced/single	16/3/3	3/1/0	1.37	.71
Living, spouse/others/alone	10/4/10	3/1/1	.85	.65
Education, school/ GCSE/degree/postgraduate	4/8/10/2	1/3/1/0	1.73	.63
Employment, working/retired/unemployed	12/3/9	1/3/1	5.71	.06
MS type, relapsing/ primary/secondary/benign	14/5/2/2	2/2/1/0	2.05	.73
Medical, yes/no	9/15	2/3	.01	.92
Medication, yes/no				
-MS	14/10	4/1	.83	.36
-Mood	9/15	2/3	.01	.92
Driving frequency				
frequent/average/infrequent	3/9/11	1/2/2	4.92	.18
-more/same/less	2/12/9	1/0/4	.42	.94
Driving, yes/no				
-Advanced	3/21	0/5	.70	.40
-Occupation	7/17	5/0	8.56	**.01***
Accidents, yes/no	4/20	2/3	1.38	.24
Offenses, yes/no	9/15	1/4	.56	.45

	Median	**IQR**	**Median**	**IQR**	**U**	**p-value**
Age, years	46.50	43-47	52	45-63	40.50	.27
MS severity, GNDS total	13	6-17	16	14-17	40	.26
MS duration, years	7	3-12	12	9-20	29	.08
Driving experience, years	27.50	22-37	30	27-40	42.50	.33

Note.χ^2 = Chi-square Test; U= Mann-Whitney Test.
*p<.01, two-tailed.

Table H5

Comparison of characteristics between RDB classifications

	Pass (n=27)	**Fail (n=2)**		
	Frequencies, *n*	**Frequencies, *n***	**χ^2**	**p-value**
Gender, female/male	16/11	1/1	0.07	.80
Marital, married/divorced/single	19/3/3	0/1/0	6.94	.07
Living, spouse/others/alone	13/4/10	0/1/1	2.38	.30
Education, school/ GCSE/degree/postgraduate	4/11/10/2	1/0/1/0	2.38	.50
Employment, working/retired/unemployed	13/4/10	0/2/0	8.24	**.02***
MS type, relapsing/primary/ secondary/benign	15/6/3/2	1/1/0/0	1.05	.90
Medical, yes/no	11/16	0/2	1.31	.25
Medication, yes/no				
-MS	17/10	1/1	.13	.72
-Mood	11/16	0/2	. 13	.25
Driving frequency				
-frequent/average/infrequent	4/10/12	0/1/1	.47	.93
-more/same/less	3/12/11	0/0/2	2.65	.45
Driving, yes/no	3/24	0/2	.25	.62
-Advanced	10/17	2/0	3.04	.08
-Occupation				
Accidents, yes/no	5/22	1/1	1.13	.29
Offenses, yes/no	10/17	0/2	1.13	.29

	Median	**IQR**	**Median**	**IQR**	**U**	**p-value**
Age, years	47	43-56	59	52-59	8.50	.14
MS severity, GNDS total	14	7-17	15	13-17	21	.63
MS duration, years	9	3-12	17	7-17	15	.34
Driving experience, years	28	23-35	40	34-40	8.5	.13

Note.χ^2 = Chi-square Test; U= Mann-Whitney Test.
*p<.05, **p<.01, ***p<.001 (two-tailed).

Table H6

Comparison between categorical variables on MSDSA and RDB scores

	MS-Driver's Screening Assessment		Rookwood Driving Battery	
	Test Statistic	**p-value**	**Test Statistic**	**p-value**
Gender	*U*=79	.33	*U*=65	.10
Marital status	*H*=0.98	.56	*H*=2.46	.10
Living arrangements	*H*=0.68	.39	*H*=.47	.50
Education level	*H*=1.29	.28	*H*=2.06	.19
Working status	*H*=1.87	.21	*H*=3.96	**.04***
MS type	*H*=3.22	.11	*H*=3.32	.08
Other medical	*U*=98	.98	*U*=76.50	.32
MS Medication	*U*=94	.84	*U*=85	.54
Mood medication	*U*=65	.13	*U*=84.50	.53
Driving Frequency Current	*H*=0.06	.71	*H*=.55	.46
Driving Frequency since MS	*H*=4.26	.07	*H*=4.80	**.03***
Advanced Driving	*U*=22	.25	*U*=36	.84
Occupation Driving	*U*=38	**.00*****	*U*=79	.31
Accidents	*U*=64	.81	*U*=53	.42
Offenses	*U*=41	**.01****	*U*=66.50	.20

Note. χ^2 = Chi-square Test; H=Kruskal-Wallis Test; U= Mann-Whitney Test
*p<.05 **p<.01 ***p<.001 (two-tailed).